

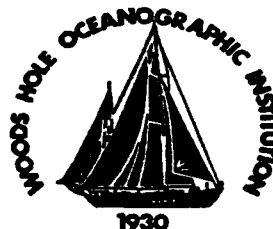
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# Woods Hole Oceanographic Institution



## Hydroblack 91

### Report of the CTD Intercalibration Workshop

by

D.G. Aubrey, T. Oguz, E. Demirev, V. Ivanov, T. McSherry,  
V. Diaconu, and E. Nikolaenko

February 1992

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Funding was provided by the National Science Foundation through Grant No. OCE-9121788, the Vetlesen Foundation, the Andrew W. Mellon Foundation, the Mobil Foundation, Inc. and the Regional Environmental Center for Central & Eastern Europe (Budapest).

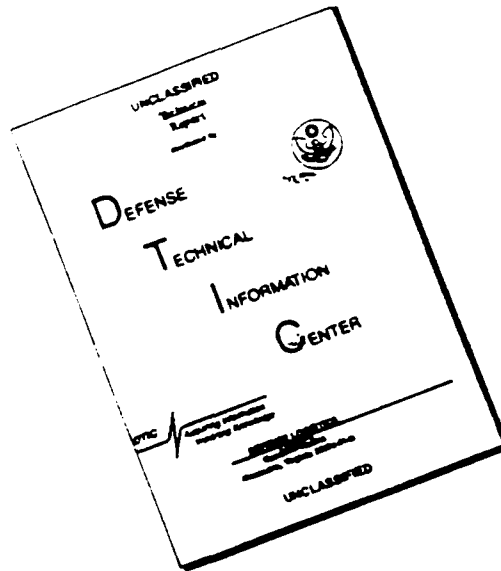
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**Woods Hole Oceanographic Institution  
Woods Hole, Massachusetts 02543**

**February 1992**

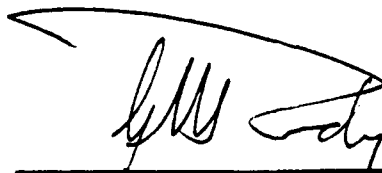
### **Technical Report**

**Funding was provided by the National Science Foundation through Grant No. OCE-9121788, the Vetleson Foundation, the Andrew W. Mellon Foundation, the Mobil Foundation, Inc. and the Regional Environmental Center for Central & Eastern Europe (Budapest).**

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**G. Michael Purdy  
Department of Geology and Geophysics**

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## ABSTRACT

An Intercalibration Workshop was held at the Woods Hole Oceanographic Institution (W.H.O.I.) from 1-10 December, 1991, for the CTD data acquired during HYDROBLACK '91. This intercalibration exercise was a prelude to an interdisciplinary HYDROBLACK '91 intercalibration to be held in Crimea, Ukraine, in February, 1992, incorporating the full suite of physical, biological, and chemical measurements acquired during the cruise.

HYDROBLACK '91 acquired for the first time a complete hydrographic, biological, and chemical data set for the entire Black Sea, to 2000 m water depth, with the participation of all Black Sea riparian countries as well as the U.S. Nearly 300 hydrographic stations were occupied to full water depth; biological and chemical measurements were made at 100 of these stations. This quasi-synoptic survey was accomplished using five ships during an interval of approximately three weeks.

Results show some disparities between CTD's from the different regions, but the intercalibrated results show a consistent and high resolution detail of the dynamic topography and other physical characteristics of the entire Black Sea basin. The intercalibrated data set is now available within each country and from W.H.O.I., and will form the basis for studies on ocean physics as well as interdisciplinary issues such as oxygen depletion within the basin and hydrogen sulfide distribution. This effort provides an intercalibrated, spatially-dense baseline against which all future and past measurements can be compared.

In spite of significant economic pressures arising from the changes in the eastern European countries, and the inadequate scientific exchange with the west during the past two decades, HYDROBLACK '91 is considered a success and a model for future international scientific and monitoring efforts throughout the Black Sea. Similar efforts are anticipated twice-yearly in the framework of the new Cooperative Marine Science Program for the Black Sea.

## GOALS OF WORKSHOP

The goals of the Intercalibration Meeting include:

- Assess quality of HYDROBLACK 1991 data
- Intercalibrate the HYDROBLACK 1991 data sets using intercalibration stations and bottle sample results.
- Discuss scientific results of HYDROBLACK 1991: compare with known results of earlier cruises to Black Sea.
- Outline scientific paper(s) that will result from hydrographic results
- Complete Technical Report on Intercalibration Exercise
- Outline agenda for February, 1992, meeting in Sevastopol for HYDROBLACK 1991.
- Discuss goals of future Hydrographic work in Black Sea; prepare additional recommendations, if necessary, to VARNA meeting results.

The agenda for the intercalibration workshop is presented as Appendix I.

## CRUISE DESCRIPTION

Five ships participated in HYDROBLACK 1991 (Table 1). These ships all provided data from several different brands of CTD's, using to the extent possible similar procedures as outlined in the HYDROBLACK 1991 cruise plan (Erdemli, Turkey, July 1991: Appendix II).

HYDROBLACK 91 accomplished nearly 300 hydrographic stations, using ships from three different Black Sea riparian countries. Two Ukrainian vessels (Kolesnikov and Parshin), two Turkish ships (Bilim and Piri Reis), and one Bulgarian vessel (Akademik) participated, occupying for the first time stations quasi-synoptically over the entire Black Sea within a period of three weeks. Station spacing was approximately 20 nm.

**TABLE 1**  
**SHIP AND CTD INVENTORY**  
**HYDROBLACK 1991**

Vessel	Country	CTD*	Dates	Number of Stations
R/V Akademik	Bulgaria	Sea Bird SBE-9	2 - 12 Sept 91	53
R/V Bilim	Turkey	Sea Bird SBE-9	5 - 23 Sept 91	104
R/V Prof. Kolesnikov	Ukraine	Istok V	9 - 29 Sept 91	94
R/V Parshin	Ukraine	Hydrozond	8 - 12 Sept 91	40
R/V Piri Reis	Turkey	Sea Bird SBE-9	7 - 17 Sept 91	16
TOTAL				307

\* Details on CTD's contained in Appendix 3 and Table 2

**TABLE 2**  
**CTD DATA SPECIFICATIONS**  
**HYDROBLACK 1991**

CTD MODEL	PRESSURE (DB)	CONDUCTIVITY (S/m)	TEMPERATURE (°C)	SAMPLE FREQUENCY (hz)
SEA BIRD SBE-9	+/- 2% (0-6000 m)	+/- 0.0004 S/m	+/- 0.003 °C	24
SEA BIRD SBE-19				2
ISTOK V	0.025% (0-60 MPa)	+/- 0.00025 S/m	0.025°C	4
HYDROZOND	0.04 - 0.6 MPa	+/- 0.0035 S/m	+/- 0.03°C	3

## DATA ASSESSMENT

Data from all ships were loaded into a SUN Sparcstation II at the Woods Hole Oceanographic Institution. These data consisted of 1-decibar (db) bin-averaged data, as provided in Varna by the individual host countries following HYDROBLACK 1991. The data consisted of ascii files of pressure (decibars), temperature (in situ, °C), salinity (psu), and density (sigma-t). In order to implement filtering and spike removal, data were converted to conductivity using the routine of Fofonoff and Millard (1983).

**Instruments:** The Akademik, Bilim, and Piri Reis used the same model of CTD: a Sea Bird SBE-9. The Kolesnikov used an Istok V CTD; the Parshin had available both a Sea Bird SBE-19 (for shallow stations) and a Hydrozond. Table 2 and Appendix 3 provide details on the different CTD's used.

**Data quality:** Data from intercalibration stations were examined first to determine the quality of the data. An assessment of the data follows. The data examined were limited to deep stations (greater than 1000 db), since the spatial and temporal variability at these depths is less than elsewhere, and the dynamic range is more limited. The deep data were the best available to examine for drift and noise problems with the instruments.

- **Akademik:** These data are of high quality. Drift of the temperature sensor was small (Figure 1), with the drift being within the dynamic upper layer, and not within the deeper bottom mixed-layer. The drift likely represents dynamics within this deeper water (spatial variability). Differences in salinity reflect the differences in temperature (Figure 2): the largest differences are above the bottom mixed layer (bml), with less than 0.005 psu difference within the bml.

Occasionally, spikes occurred in salinity in the deeper waters. Spikes also occurred near the seasonal thermocline. The shallow spikes occurred because of ship heave due to heavy seas, combined with the slow lowering speed in the upper 100 meters (Figure 3). The lowering speed of 0.5 m/sec was modulated by surface waves, resulting in contaminated data within the strong gradients of the seasonal thermocline. In deeper waters, spikes (Figure 2) appeared that were linked with missing data (the modulo count on the Sea Bird was higher than 24). This resulted in both positive and negative spikes in conductivity and temperature, and hence in salinity. The cause of this spiking appears to be cable-related, either due to slip-ring problems or other cable problems.

- **Bilim:** These data appear to be of high quality. Temperature and salinity both appeared uniformly varying and noise-free. Long-term drift is small (less than 0.005 degrees C and 0.005 psu within the bml during the entire cruise: Figures 4 and 5). Convergence within the bml suggests the drift is due to spatial variability or dynamical changes. No spiking was observed in these data.

- **Kolesnikov:** These data were of high quality, but were noisier than the Bilim and Akademik data. The temperature signal taken at deep stations throughout the three weeks of sampling show several features (Figure 6):

- Discontinuities in temperature, due to coarse discretization (reporting to 0.00x degrees C instead of 0.000x degrees C).

- Staircases, where temperature "stuck" at a uniform value for more than 25 meters. For instance, one staircase occurred at 9.015°C throughout the cruise.

- Space/time variability, with a spread of about 0.02 degrees C throughout the cruise. Since the temperatures shown are actual temperatures (not potential), the bml cannot be observed in temperature as a uniform layer, but these same 0.02°C differences persist in the bml itself at 1800 db levels and deeper. Since the bml is so uniform horizontally and vertically, this disparity represents a drift in the sensor.

## Akademik Drift Test

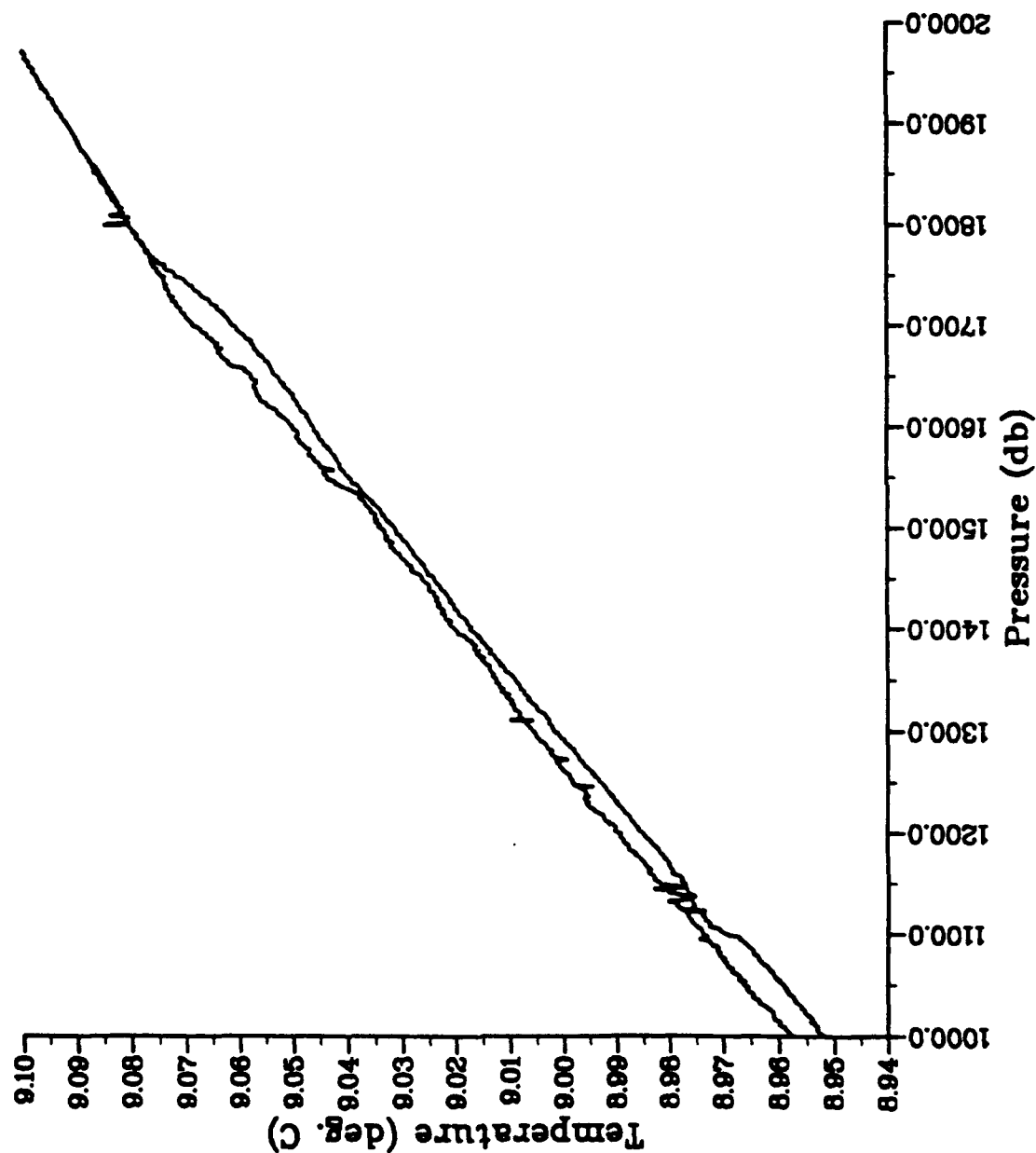


Figure 1: Temperature versus depth from the Akademik, during HYDROBLACK '91. Agreement of actual temperature within the bottom mixed layer shows no appreciable temperature drift through time. Spikes in the temperature signal appear to result from cable weakness, slip-ring noise, or perhaps a bad connector.

# Akademik Drift Test

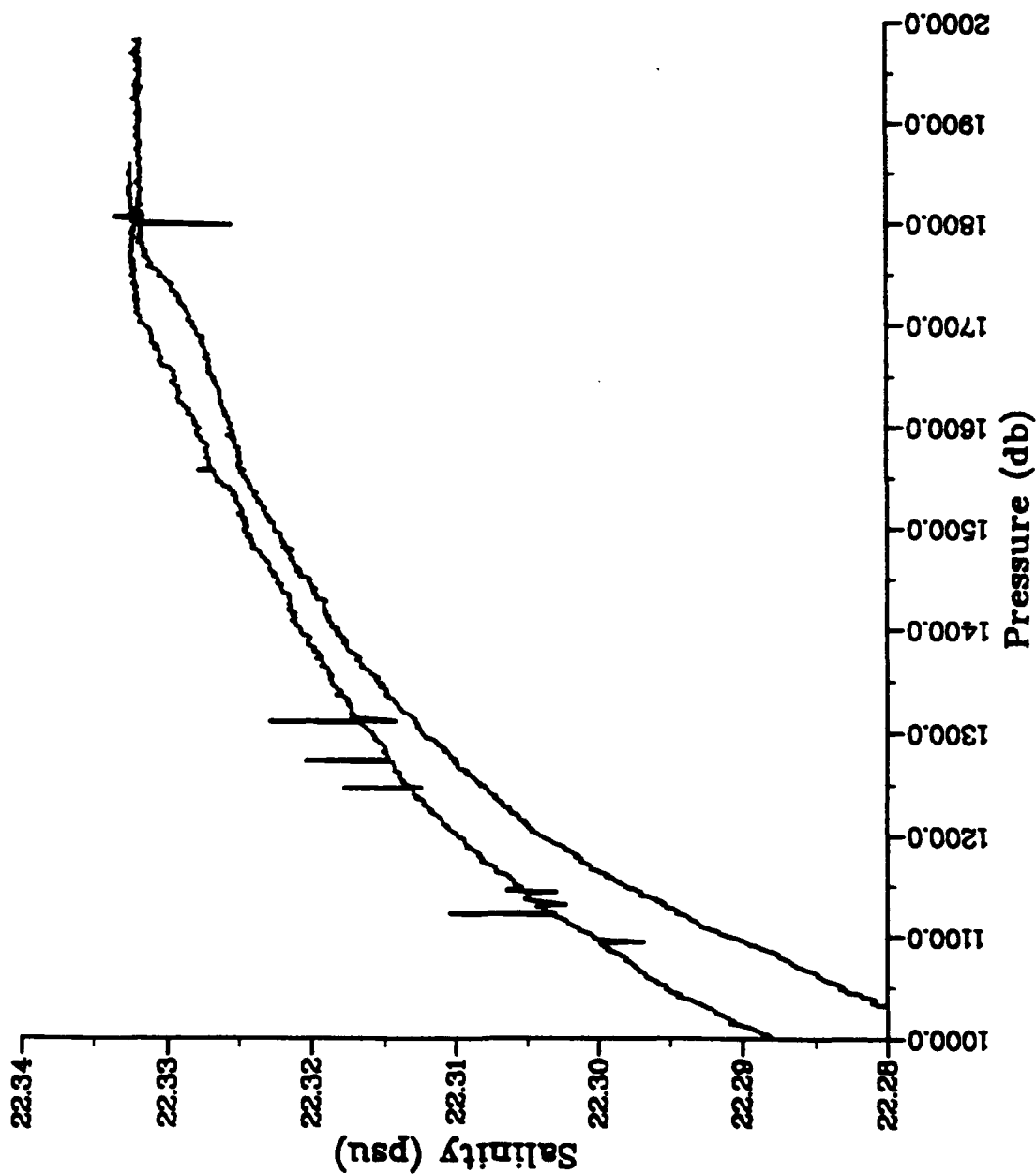


Figure 2: Salinity versus depth calculated for the Akademik casts of Fig. 1. The temperature spikes show up as marked salinity spikes. Salinity in the bottom mixed layer agrees well for the two casts.

## Akademik: Spiking within Thermocline

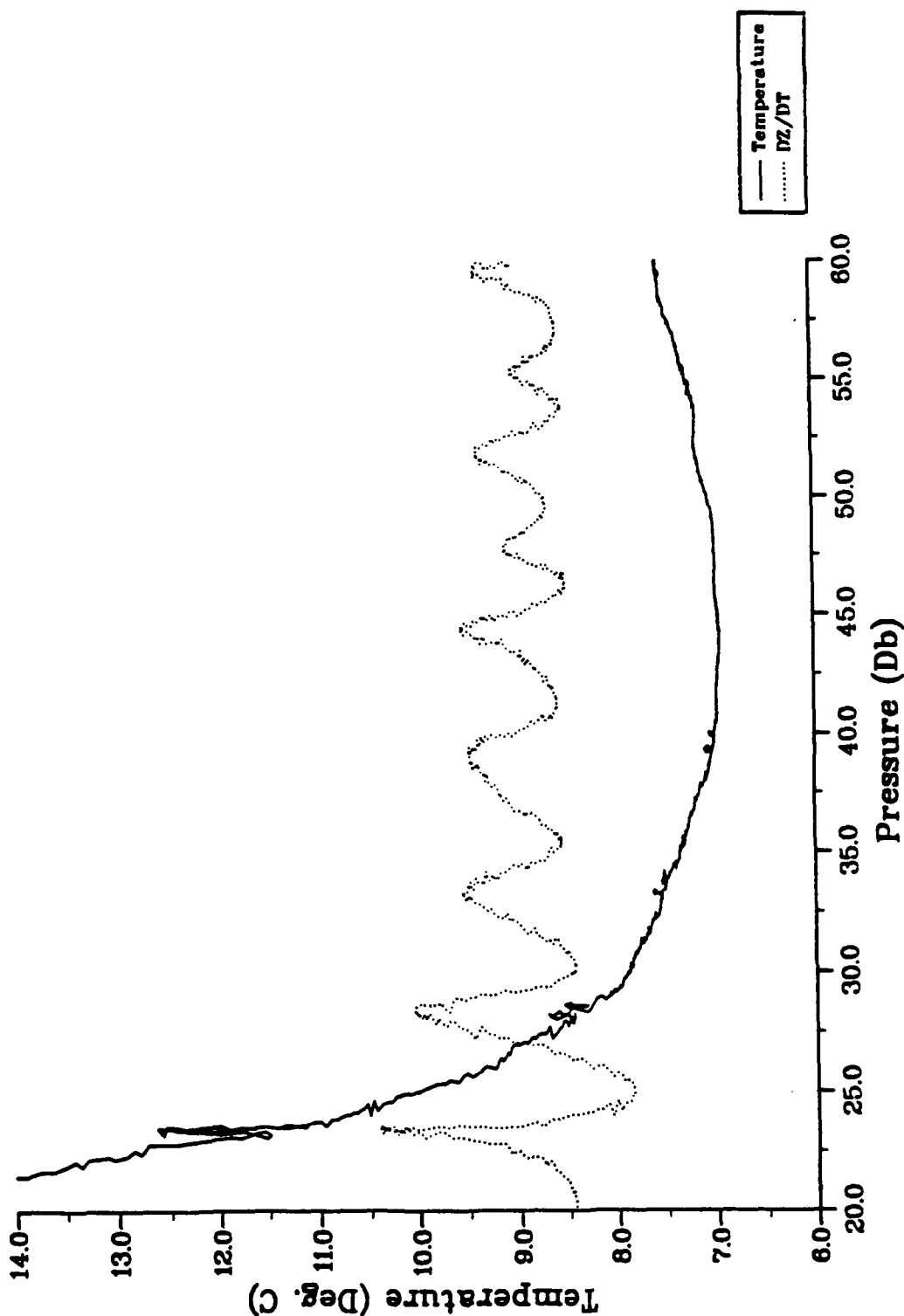


Figure 3: Temperature versus depth in the upper 60 db for the Akademik at one station. The solid line is the temperature from the CTD. The dashed line shows low-pass filtered vertical CTD velocity. Spikes in temperature within the thermocline occur when the vertical velocity changes rapidly, most likely due to ship motion caused by surface waves. The spike cannot be removed by simple filtering, and was exacerbated by too slow a lowering speed through the thermocline.



## Bilim Drift Test

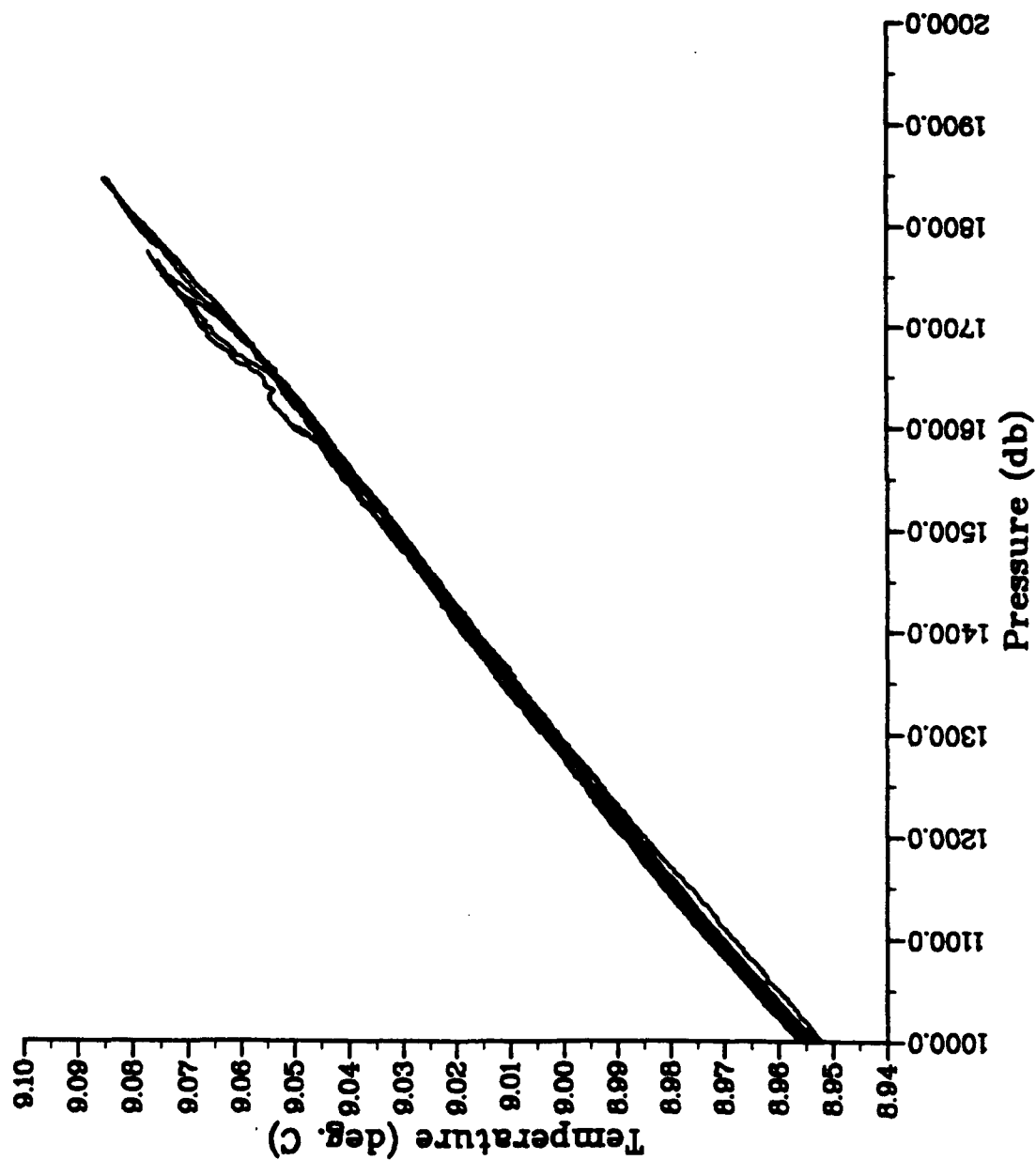


Figure 4: Temperature versus depth from the Bilim, during HYDROBLACK '91. Agreement of temperatures throughout most of the water column over the entire southern Black Sea during a period of two weeks indicates stability of the thermistor in the Bilim CTD. Wire length restrictions prevented the Bilim CTD from entering far into the bottom mixed layer.

## Bilim Drift Test

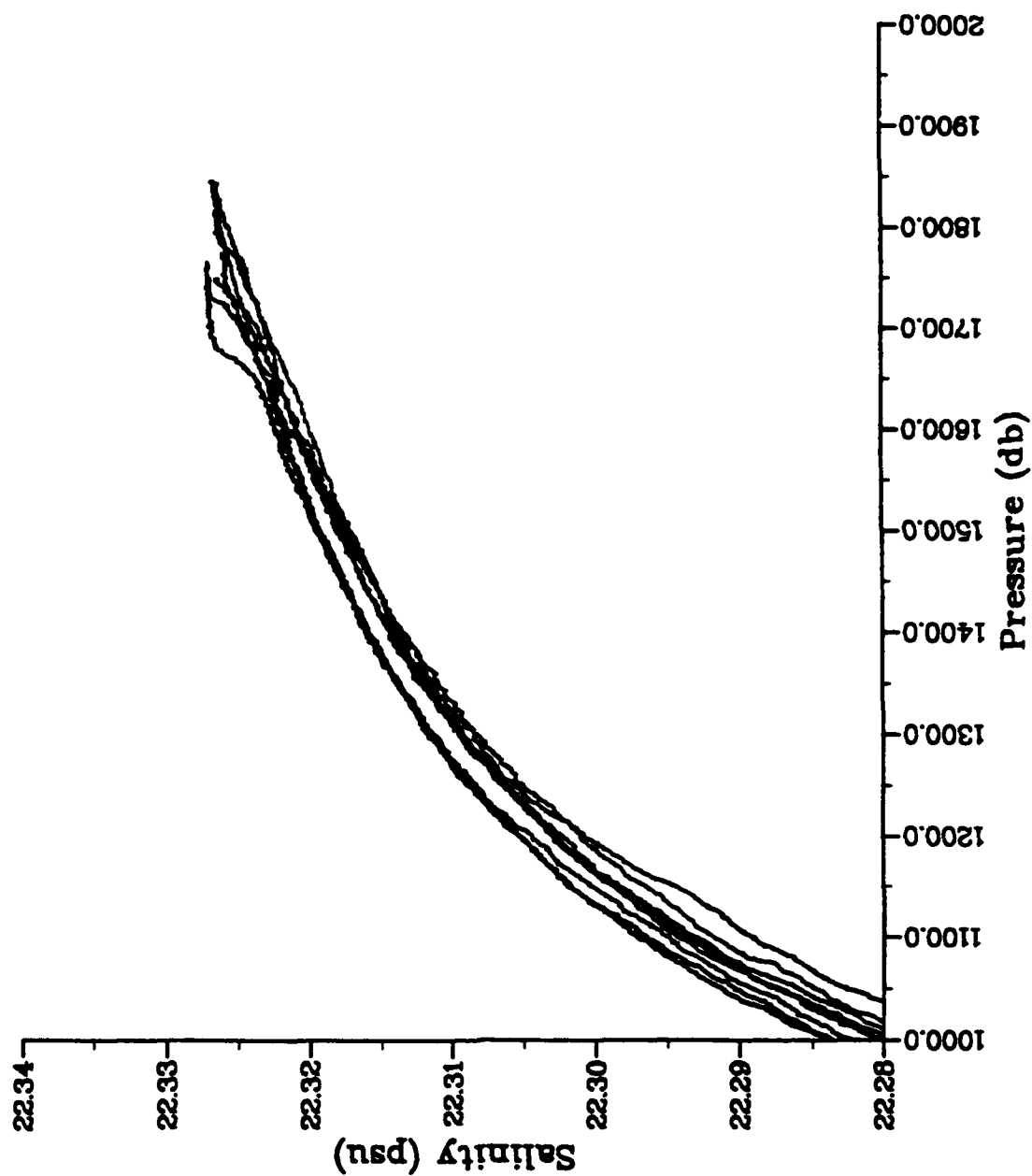


Figure 5: Salinity versus depth calculated for the Bilim casts of Fig. 4. As for temperature, the salinity data for the different casts are similar, especially near the bottom where they converge to a value of approximately 22.325 psu.

## Kolesnikov Drift Test

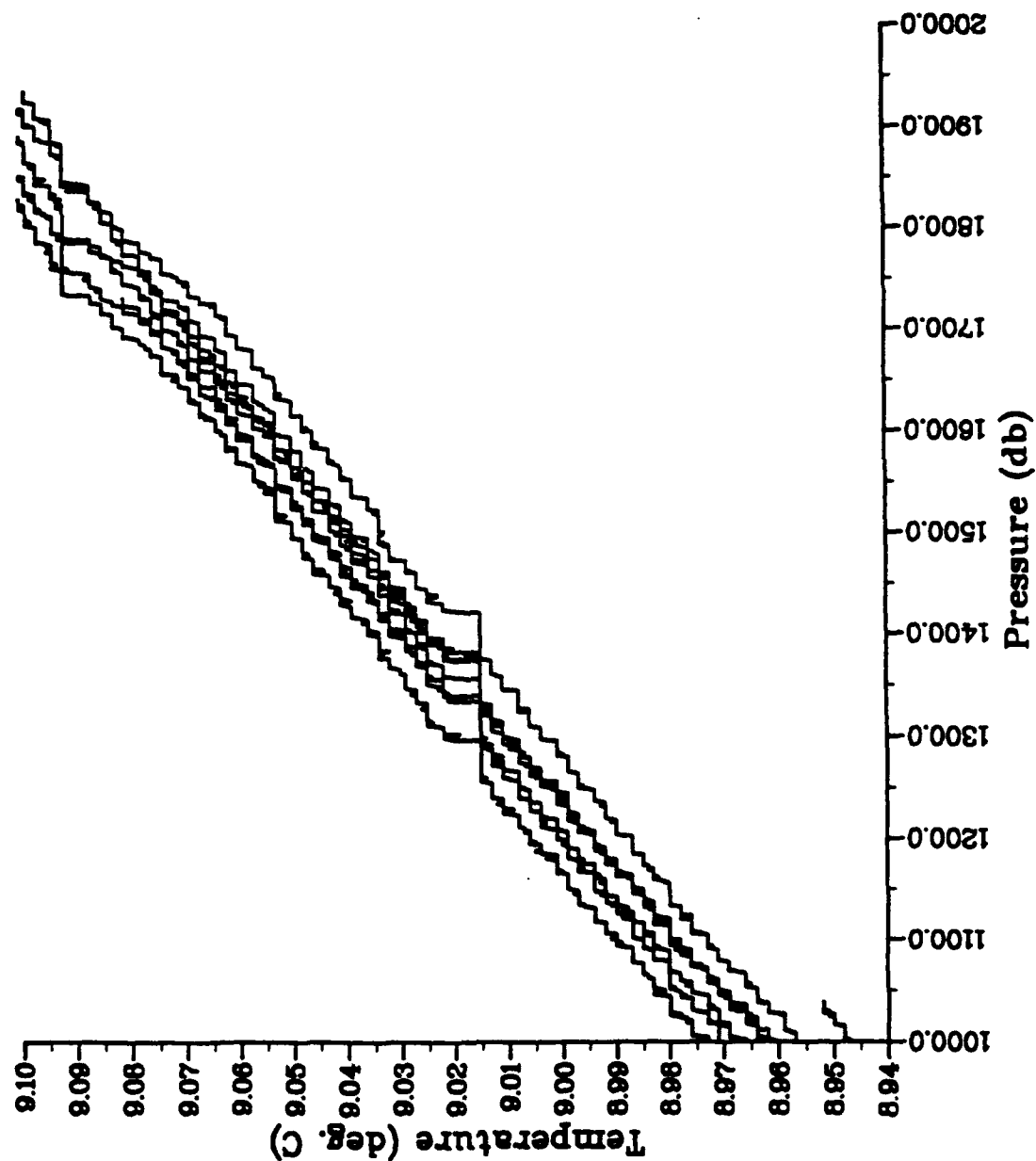


Figure 6: Temperature versus depth from the Kolesnikov, during HYDROBLACK '91. Temperature had several problems: the discretization interval is apparent in the graph by the jagged changes. Also, there is considerable drift in temperature (by about  $0.02^{\circ}\text{C}$ ) during the course of the experiment. Finally, temperature sticks at certain levels (e.g.,  $9.015^{\circ}\text{C}$ ) for tens of meters water depth.

The temperature drift was investigated through time, to see if the difference were linear as reported in a 1990 joint Soviet-Turkish Black Sea hydrographic experiment. Unfortunately, this drift was not linear (Figure 7).

The conductivity was uniform throughout the cruise, showing no drift. Salinity, however, reflects the temperature drift by showing large scatter in salinities (0.01 psu and greater) throughout the cruise (Figure 8).

- Parshin: These data were taken with a coarse-resolution instrument (Hydrozond), and some data were taken also by a SeaBird SBE-19, before this latter instrument's pressure sensor failed halfway through the cruise (operator error). The SBE-19 data were of high quality, showing little spiking or other anomalies. The Hydrozond data, however, had greater difficulties. The Hydrozond's conductivity cell stopped working, so the sampling procedure consisted of lowering the thermistor and pressure sensors, examining the data, and then taking bottle samples analyzed on board for salinity. The result was a coarse resolution varying from a few meters to hundreds of meters in the deep stations. The accuracy of the instruments also is poor compared to the Sea Birds or Istok, so the deeper Parshin data were discarded. Only the shallow water data were used in this analysis.

- Piri Reis: Only a few stations were run by the Piri Reis. These data appeared of similar quality as the Bilim and Akademik data. Temperature variability (Figure 9) was near zero in the bml, but showed a little structure above the bml. In salinity (Figure 10), the same variability shown by temperature exists, but the salinity in the bml is always uniform. The drift is small (less than 0.02 psu).

- Knorr 1988: Although not part of this cruise, the KNORR 1988 data were examined for time and space variability. These data (reported by Murray et al. 1989 and several others) were high quality observations against which the present data could be compared. Two sets of profiles were examined in detail, consisting only of deep stations (to about 2000 db). The first set of profiles consists of stations throughout the Turkish part of the Black Sea (Figure 11), which would be indicative of spatial variability. The second set is taken from a single station, occupied repeatedly throughout the four-month duration of the Knorr cruise in the Black Sea.

Space variability in temperature is relatively small, with negligible variability within the bml (Figure 12). Variability between 1000 m and 2000 m was approximately 0.05 °C. Space variability in conductivity similarly was small, and negligible within the bml (Figure 13). Variability within the 1000-1800 db levels was approximately 0.002 S/m). Finally, spatial variability in salinity arising from the conductivity and temperature variability (Figure 14) is of the order of 0.005 psu in the bml. Variability is greater between 1000 and 2000 db levels.

Time variability in the Knorr data is similar as the spatial variability. The time variability in temperature (Figure 15) is of the order of 0.005 °C. Time variability in conductivity (Figure 16) is similar, with one higher measurement which might represent a different instrument. The variability in temperature and conductivity translate to a variability in salinity (Figure 17) of about 0.003 psu, with the exception of the one measurement having a high conductivity, which has a salinity within the bml higher by about 0.008 psu.

## Kolesnikov Trend vs. Station 226

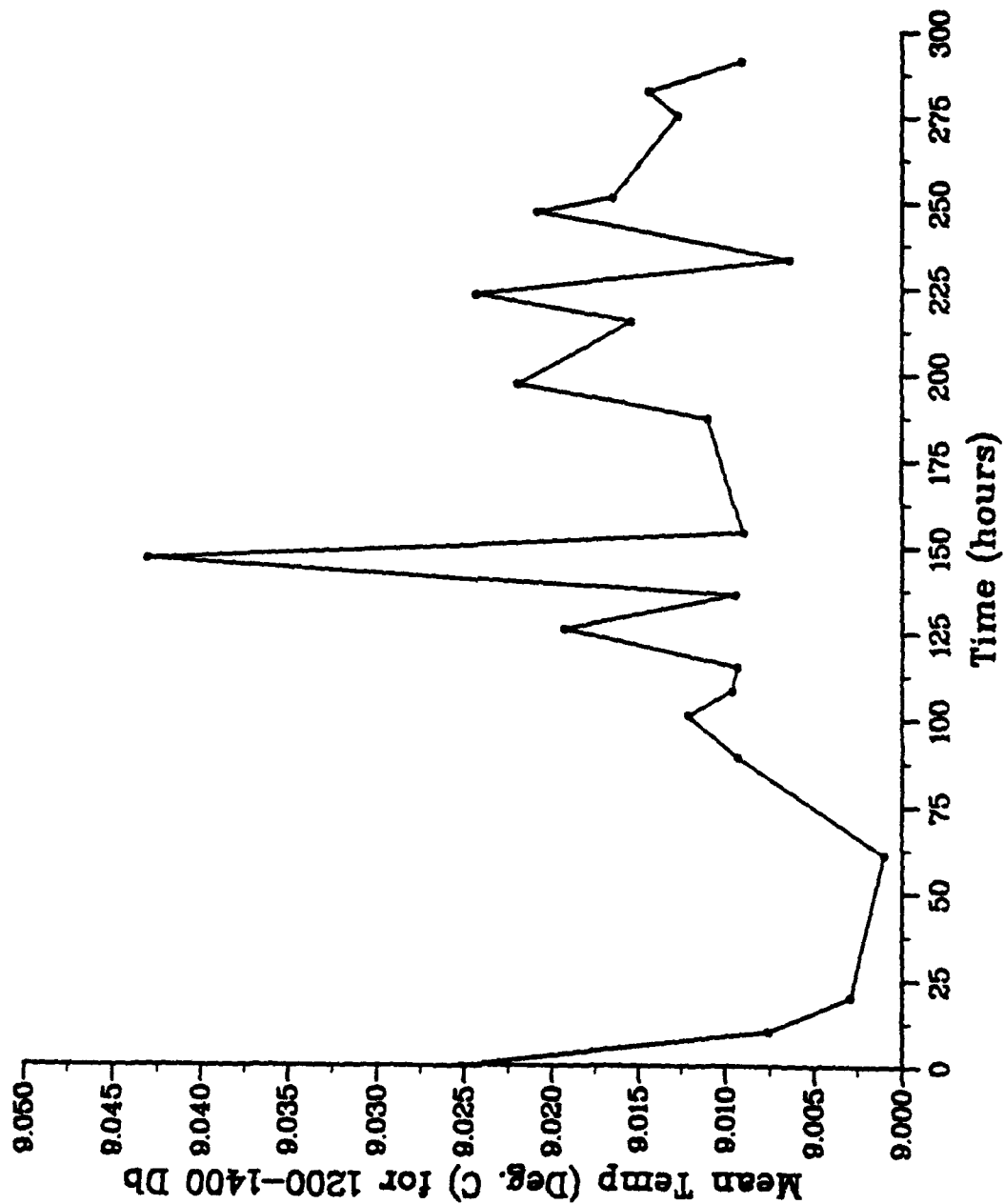


Figure 7: Mean temperature for the pressure levels of 1200-1400 db for the Kolesnikov. Horizontal axis is time from the first hydrographic cast of the Kolesnikov. The variability in temperature through time shows that a simple time-dependent temperature correction was not appropriate for the Kolesnikov data.

## Kolesnikov Drift Test

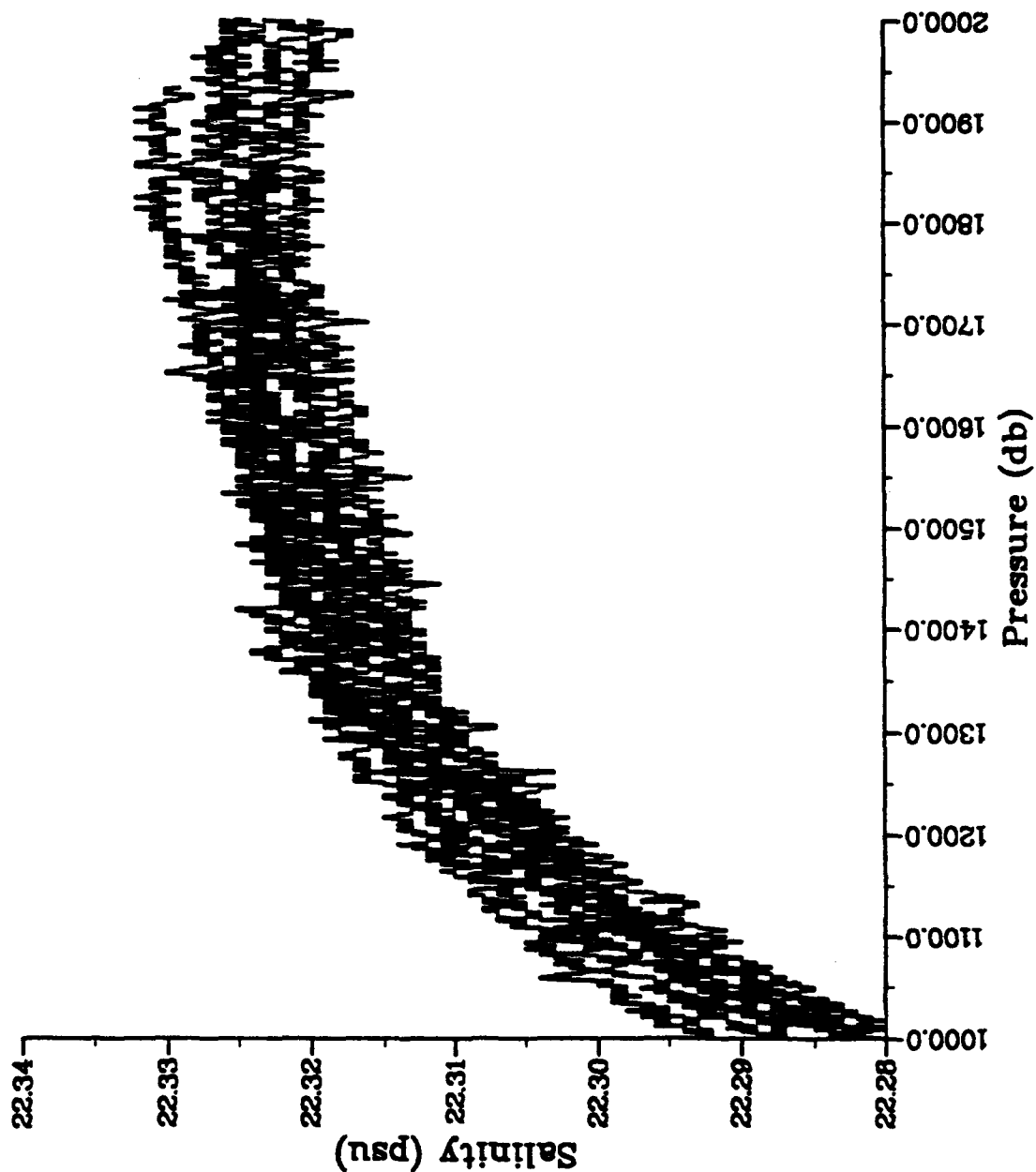


Figure 8: Salinity versus depth calculated for the Kolesnikov casts of Fig. 6. Salinity drift indicates several features: There is a notch-structure resulting from the coarse resolution of the thermistor. Salinity remains constant in several regions due to the sticking of the temperature at certain levels. Finally, there is strong curvature in the deeper waters, which result from a depth-dependent over-correction made to the conductivity measurement. This correction has the effect of artificially flattening salinity at greater depths.

## Piri Reis Drift Test

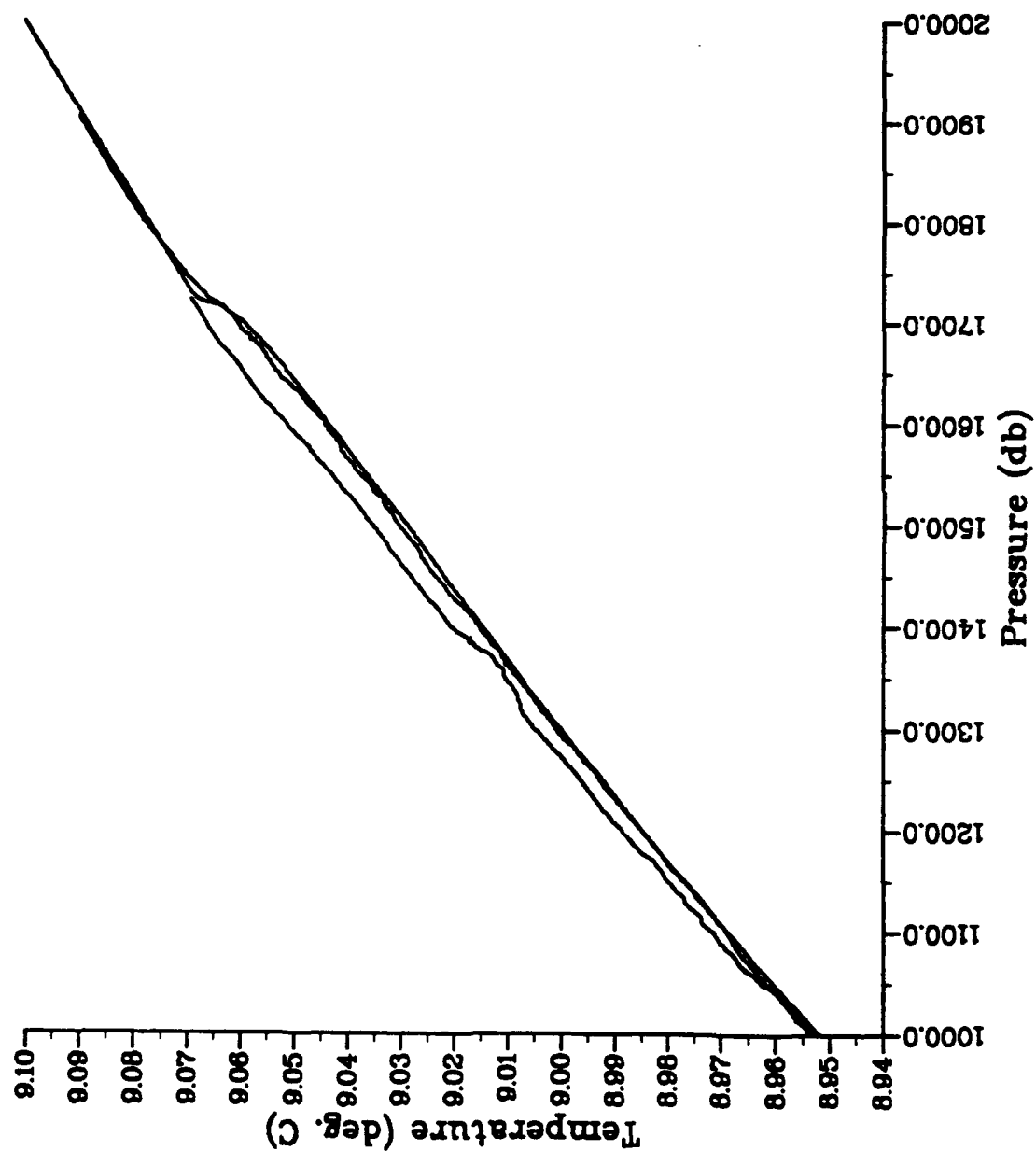


Figure 9: Temperature versus depth from the Piri Reis, during HYDROBLACK '91. Agreement of temperatures throughout most of the water column over the western Black Sea during a period of two weeks indicates stability of the thermistor in the Piri Reis CTD. In particular, actual temperature in the bottom mixed layer is nearly identical (to better than 0.001°C).

## Piri Reis Drift Test

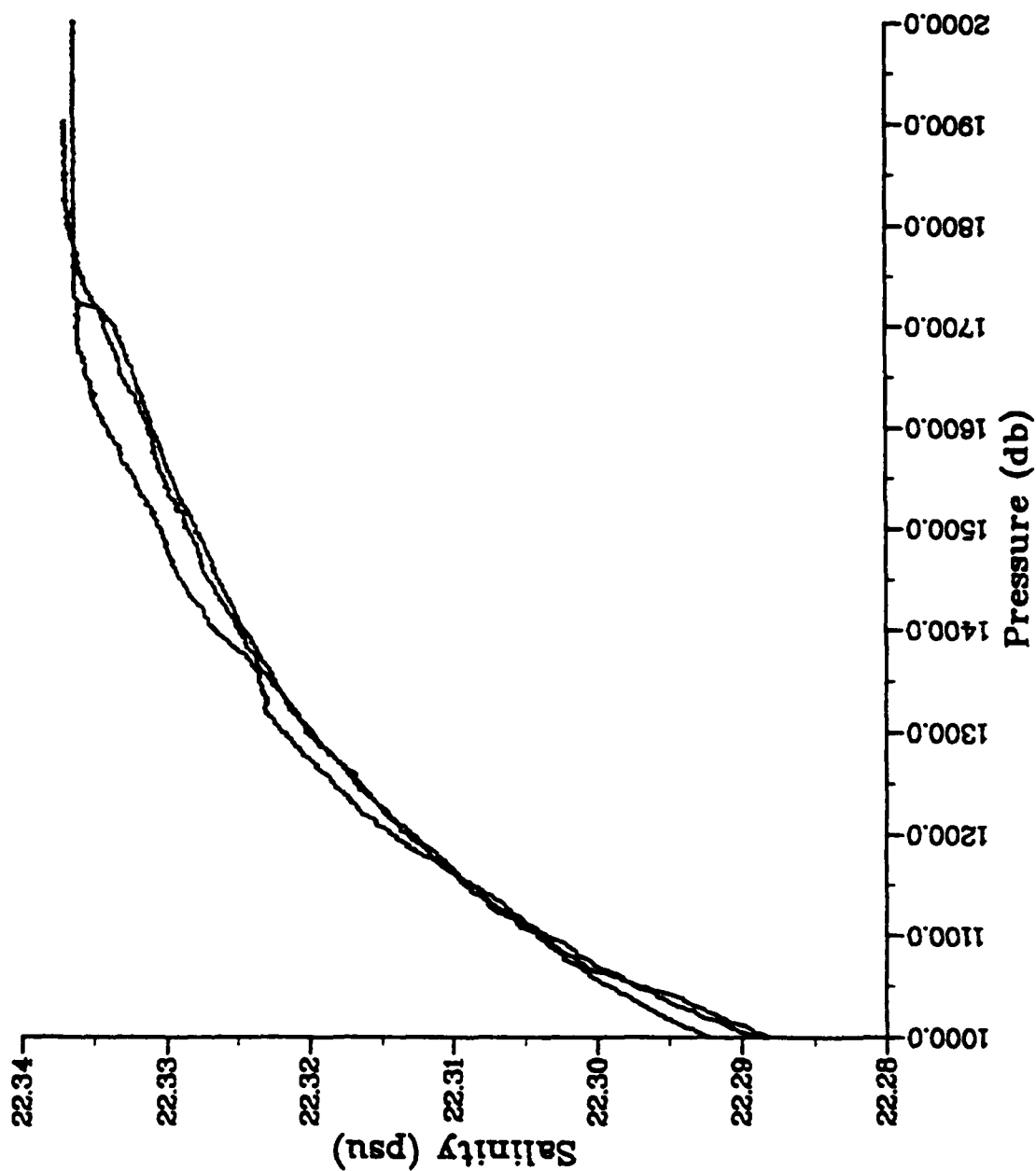


Figure 10: Salinity versus depth calculated for the Piri Reis casts of Fig. 9. As for temperature, the salinity data for the different casts are similar, especially near the bottom where they converge to a value of approximately 22.335 psu. This convergent value is higher by about 0.01 psu than the equivalent values for the Bilim.



## Knorr Stations

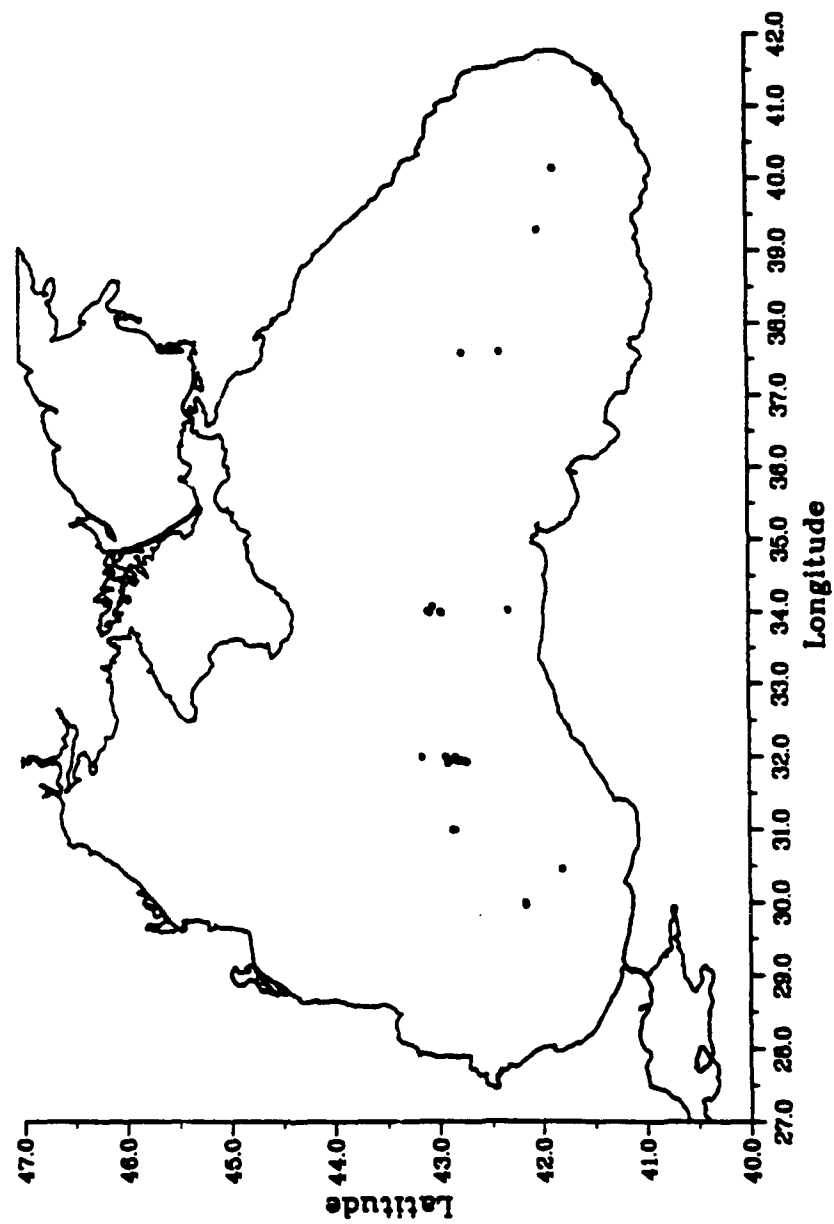


Figure 11: Positions of Knorr hydrographic stations from 1988.

## Knorr: Space Variability

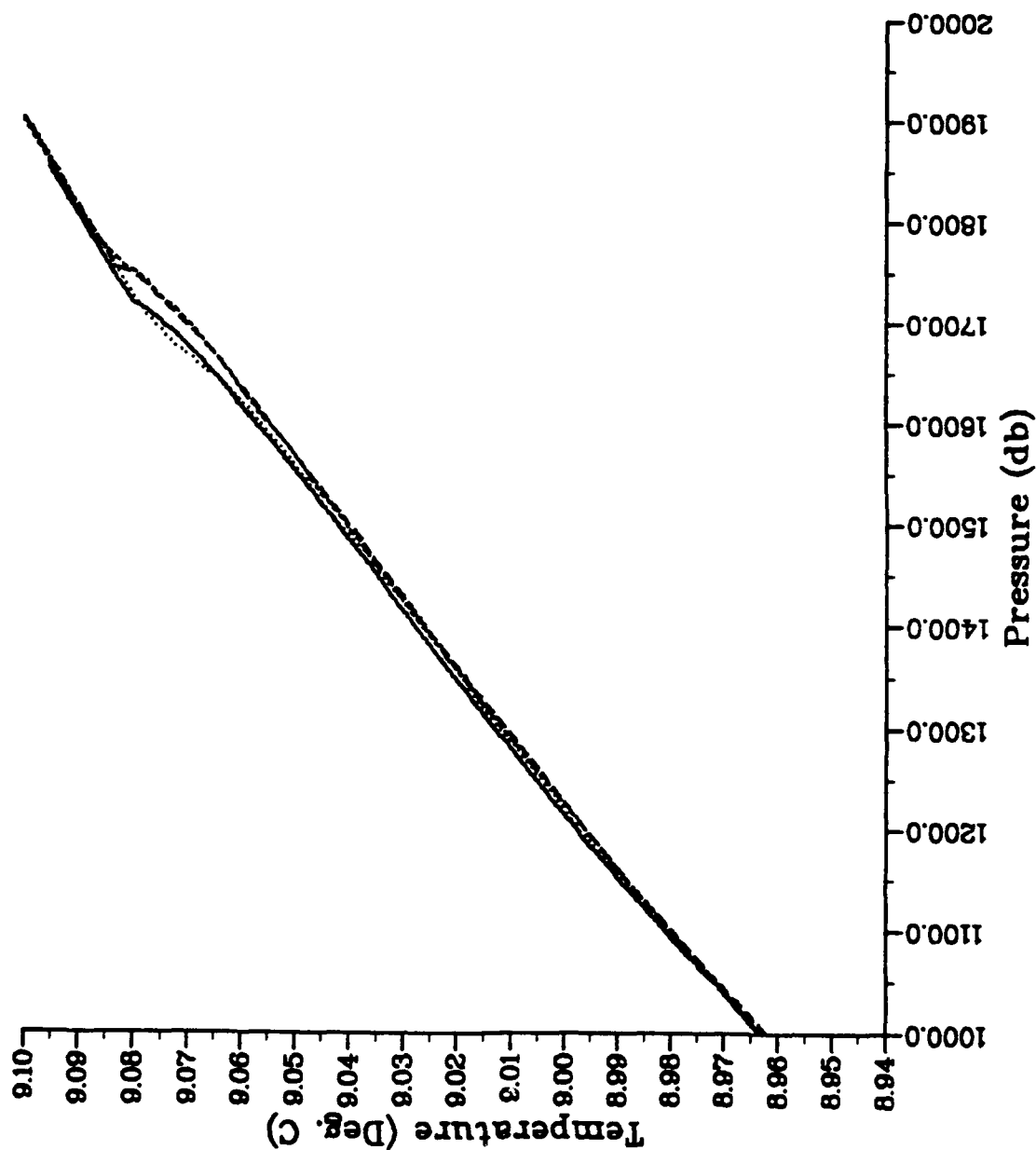


Figure 12: Temperature versus depth from the Knorr, for 1988, for some deep stations. Agreement of temperatures throughout most of the water column over the entire southern Black Sea during a period of several months indicates stability of the thermistor in the Knorr CTD. In particular, actual temperature in the bottom mixed layer is nearly identical (to less than  $0.001^{\circ}\text{C}$ ).

## Knorr: Space Variability

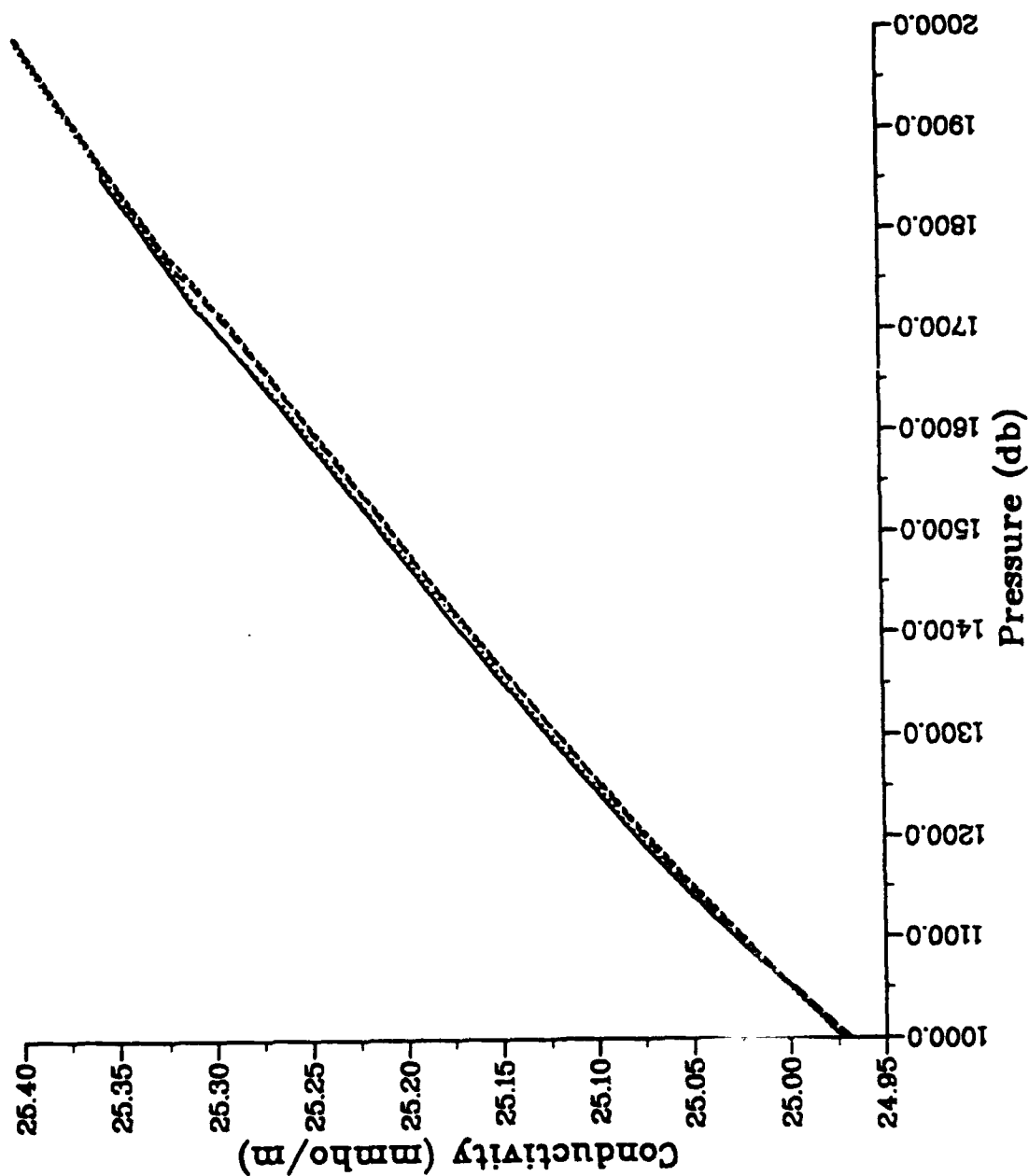


Figure 13: Conductivity versus depth from the Knorr, for 1988. Agreement of conductivity throughout most of the water column over the entire southern Black Sea during a period of several months indicates repeatability of the conductivity cell in the Knorr CTD, especially in the bottom mixed layer.

## Knorr: Space Variability

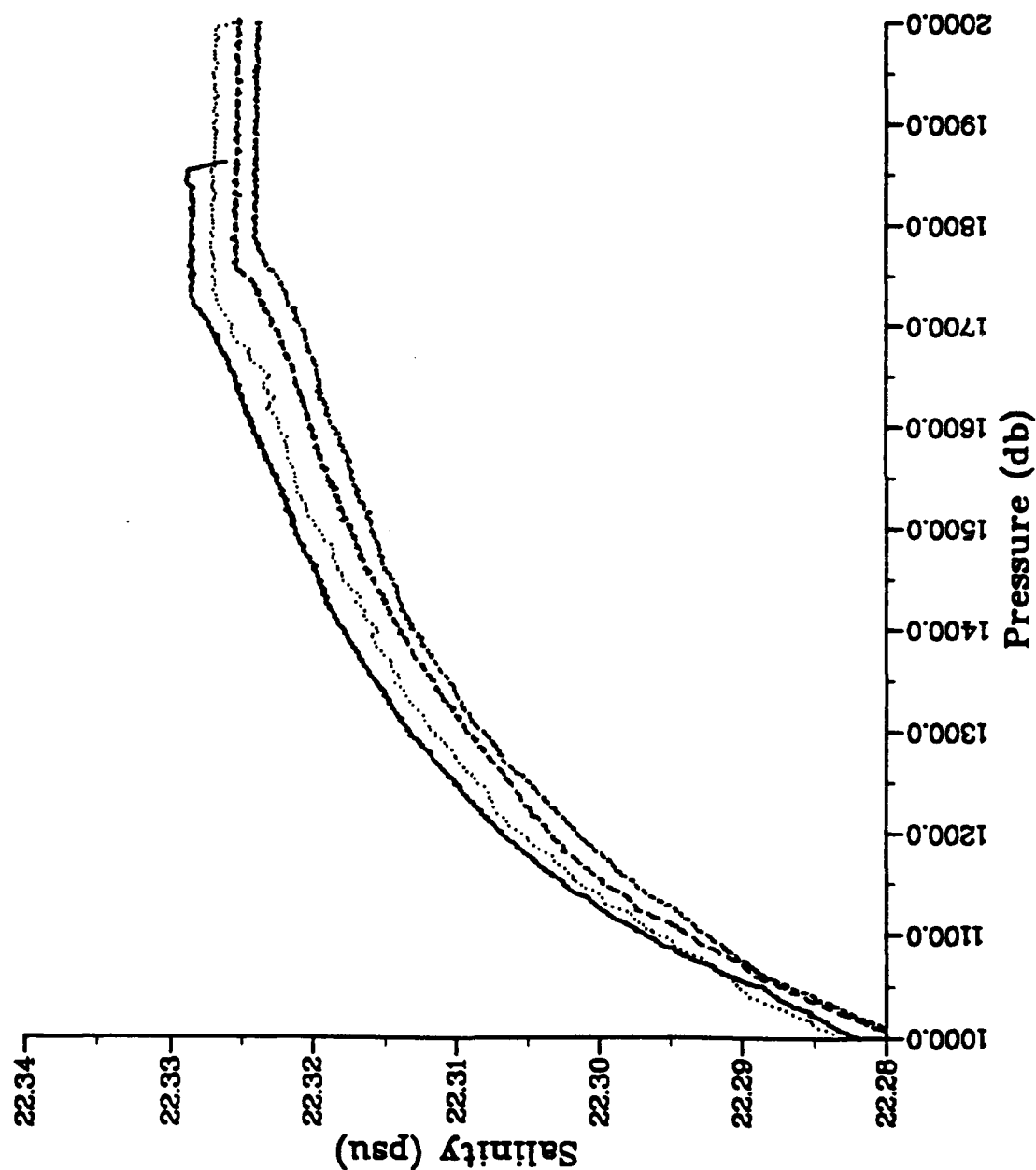


Figure 14: Salinity versus depth from the Knorr, for 1988, for some deep stations. Agreement of salinity throughout most of the water column over the entire southern Black Sea during a period of several months indicates good performance of the Knorr CTD, especially in the bottom mixed layer. Differences in the bottom mixed layer are about 0.005 psu.

## Knorr: Time Variability

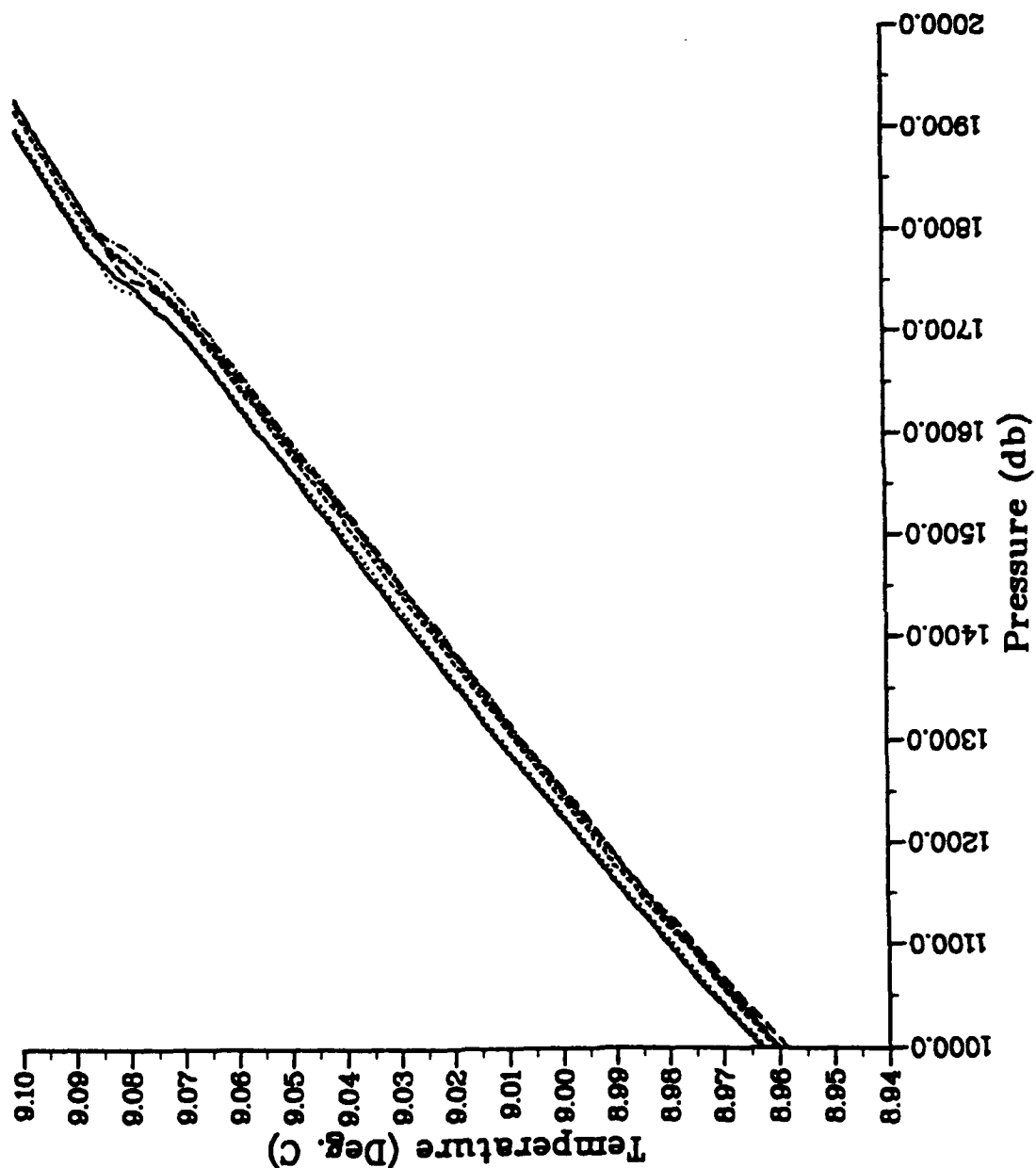


Figure 15: Temperature versus depth from the Knorr, for 1988, for a single deep station occupied repeatedly during a period of several months. Agreement of temperatures throughout most of the water column during a period of several months indicates stability of the thermistor in the Knorr CTD. In particular, actual temperature in the bottom mixed layer is nearly identical (to better than 0.005°C).

## Knorr: Time Variability

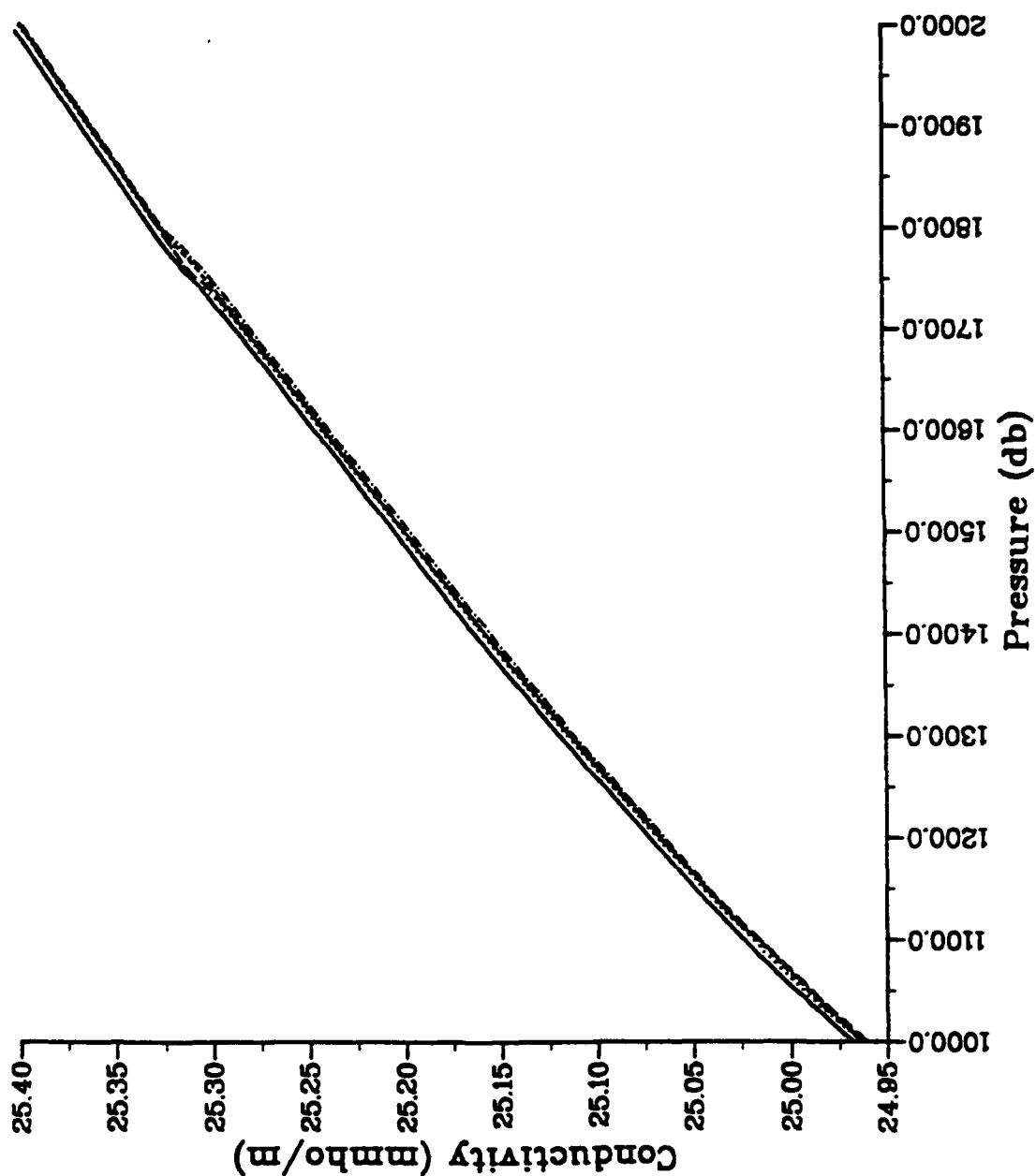


Figure 16: Conductivity versus depth from the Knorr, for 1988, for a single station during a period of several months. Agreement of conductivity throughout most of the water column during a period of several months indicates stability of the conductivity cell in the Knorr CTD, especially in the bottom mixed layer, where differences are on the order of 0.002 S/m.

## Knorr: Time Variability

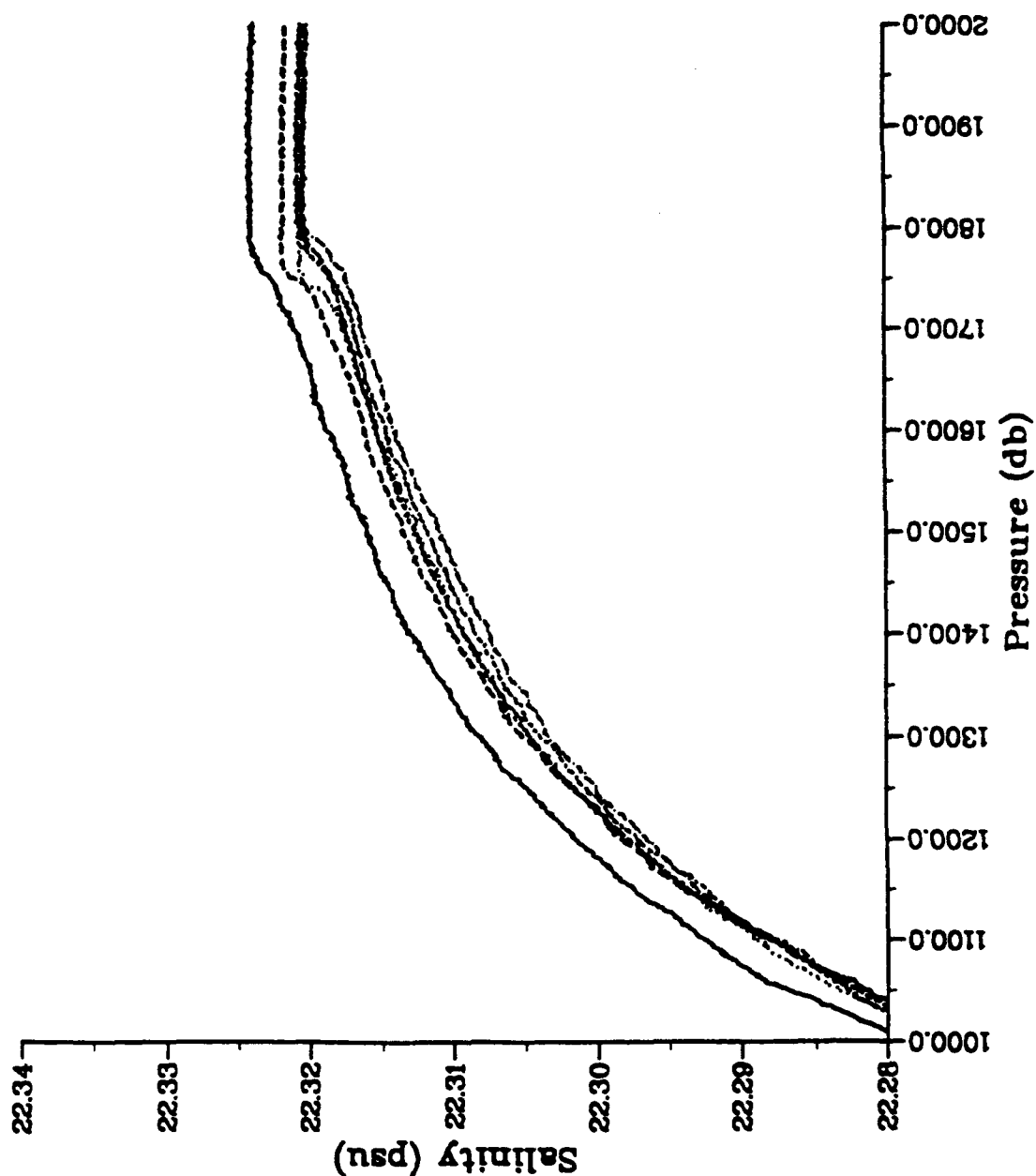


Figure 17: Salinity versus depth from the Knorr, for 1988, for a single deep station taking data during a period of several months. Agreement of salinity throughout most of the water column during a period of several months indicates good performance of the Knorr CTD, especially in the bottom mixed layer. Differences in the bottom mixed layer salinity are about 0.005 psu, the same level as the spatial variability described in Fig. 14.

## DATA INTERCALIBRATION

The intercalibration was accomplished on two bases: comparison of results from common stations, and the use of bottle samples to measure salinity. The two intercomparisons are described below here.

**Intercalibration stations:** The HYDROBLACK 91 cruise plan (Appendix II) laid out a series of intercalibration stations for the cruise (Figure 18), at which at least two ships would acquire measurements to the full water depth or to 2000 db, whichever was less. The two ships were to occupy these stations as synoptically as possible, but rough weather, poor communications at times, and instrument difficulties prevented some simultaneous measurements. On one occasion however, two ships (Akademik and Parshin) met for a simultaneous cast, even sharing a meal!

The goal of the intercalibration station was to provide in situ measurements of instrument performance, so the data could be compared and, if necessary, shifted for grouped analysis. The intercalibration was performed on temperature and conductivity, with comparisons made for salinity. Two intercalibration stations are presented for illustration. Station N30N45 (see Table 3 for a listing of station identification, analysis code, time and date of sampling, water depth, etc.) was occupied by the Akademik, Bilim, and Kolesnikov (Figure 19), and illustrates some of the difficulties in the sampling. The Bilim salinities are below those of the other two CTD's, except in deepest water where the Kolesnikov salinity intercepted the Bilim salinity. The Kolesnikov salinity also is noisy. The Akademik data are uniformly above the Bilim salinities, and are much less noisy except for the cable noise described above. For comparison, this station can be compared with Knorr data added (Figure 20), comparing now at greater depths (deeper than 1400 db). Here, two Knorr stations (one in the east and one in the west), superimpose close to the Bilim data. The Kolesnikov suffers apparently from a depth dependency (discussed later), and the Akademik salinities are uniformly high.

**Spike removal and filtering:** Analysis of the data indicate that some filtering and spike removal was required. For all stations, filtering and spike removal was limited to levels greater than 500 db, to avoid filtering in the region of greatest gradients where such filtering could alter the structure of the profiles. Also, the filtering required is much less than the dynamic signature within these shallower regions, so filtering was not performed shallower than this level.

The filter used in all analyses was a tenth order Butterworth filter with a cutoff at 0.05 per meter. This filter was selected because of its lack of stopband and passband ripple. Although other filters could have been used, these one gave good performance without altering the shape of the profiles. In order to avoid phase shifts, the filtering was performed both forwards and backwards. However, this procedure gave unacceptable loss of data near the greater depths where the intercalibration occurred. To avoid this, the filter was run only in a forwards direction, and then shifted linearly to account for the filter loss at the end (40 db of data lost). Although the phase error is not linear with frequency for this filter, the narrow frequencies left in the data could be represented accurately by a simple frequency-independent shift. This was verified by repeated analysis both one way and forwards-and-backwards, and comparing the differences. The filter is described, for instance, in Oppenheim and Schaffer (1975).

Only conductivity and temperature were filtered. Both were filtered with identical filters. The specific signal conditioning applied to each data set is described below.



# Hydro-Black 1991 Station Network

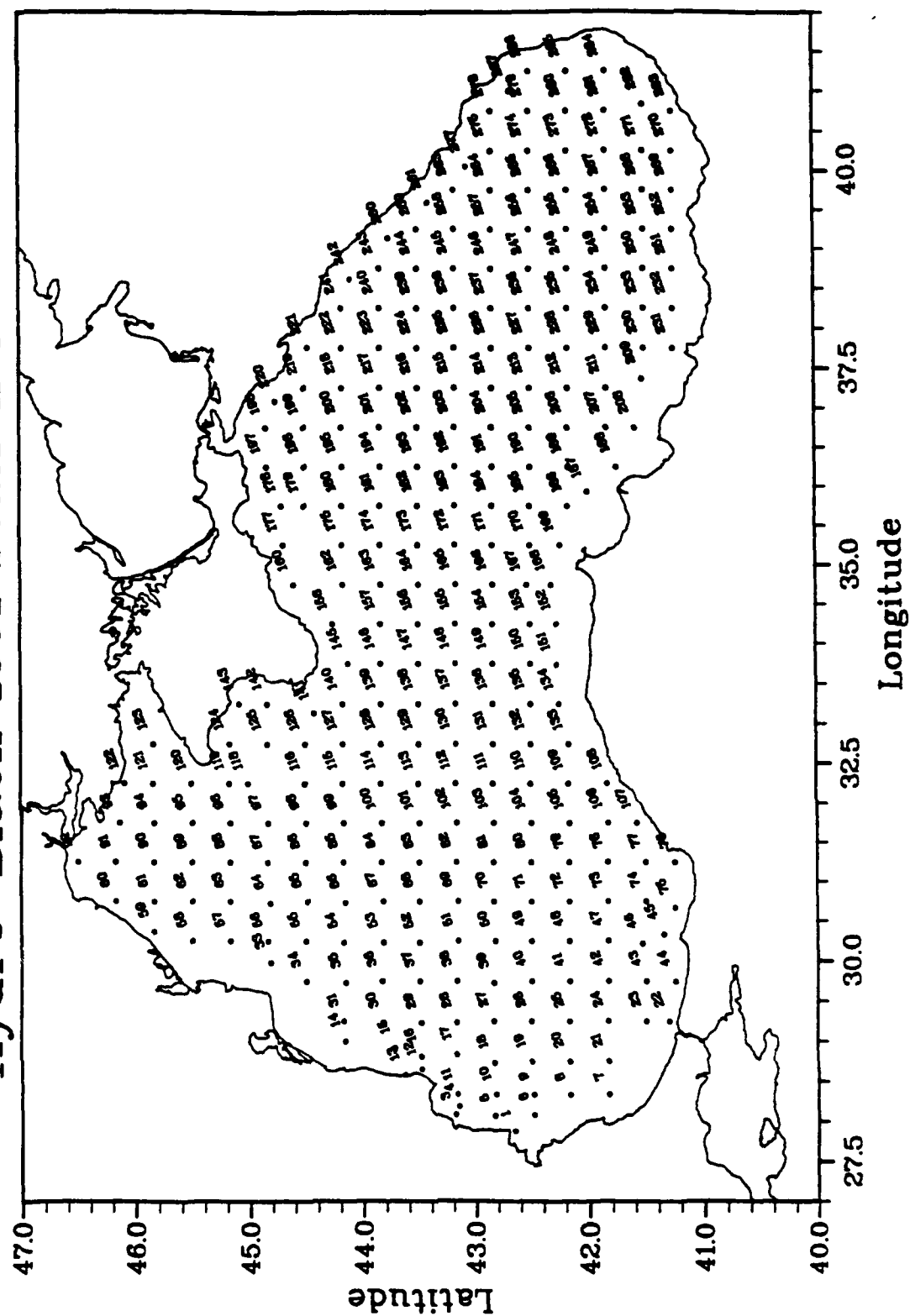


Figure 18: Station numbers and locations for HYDROBLACK '91 hydrographic casts.

# N30N45: Bilim, Akad., Koles.

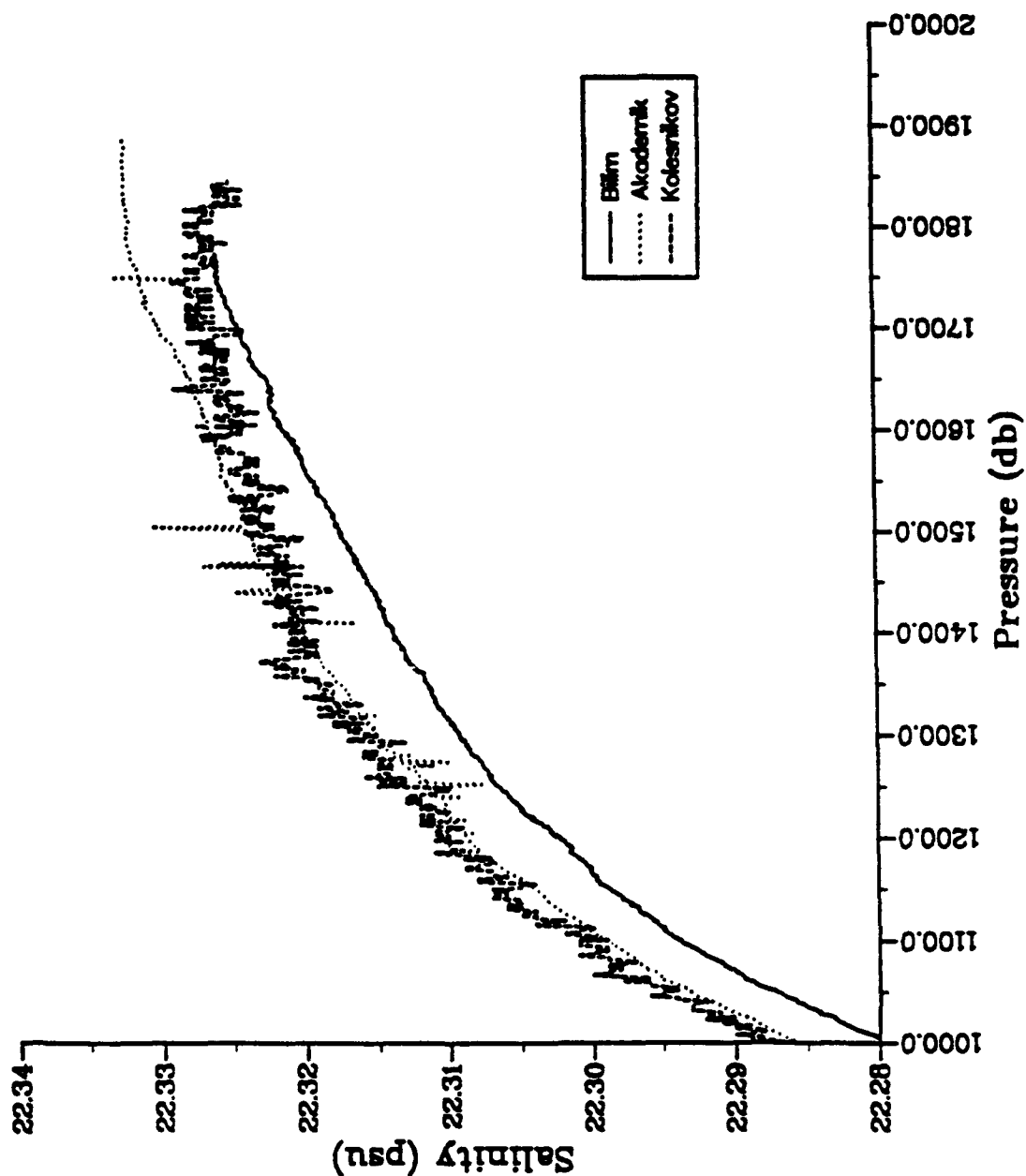


Figure 19: Comparison of non-intercalibrated salinity measurements at Station N30N45 for the Bilim, Akademik, and Kolesnikov. The overcorrection of the Kolesnikov data is depicted in the straightening of the salinity signal with depth, and crossing of the other two CTD's.

## N30N45 Intercomparison

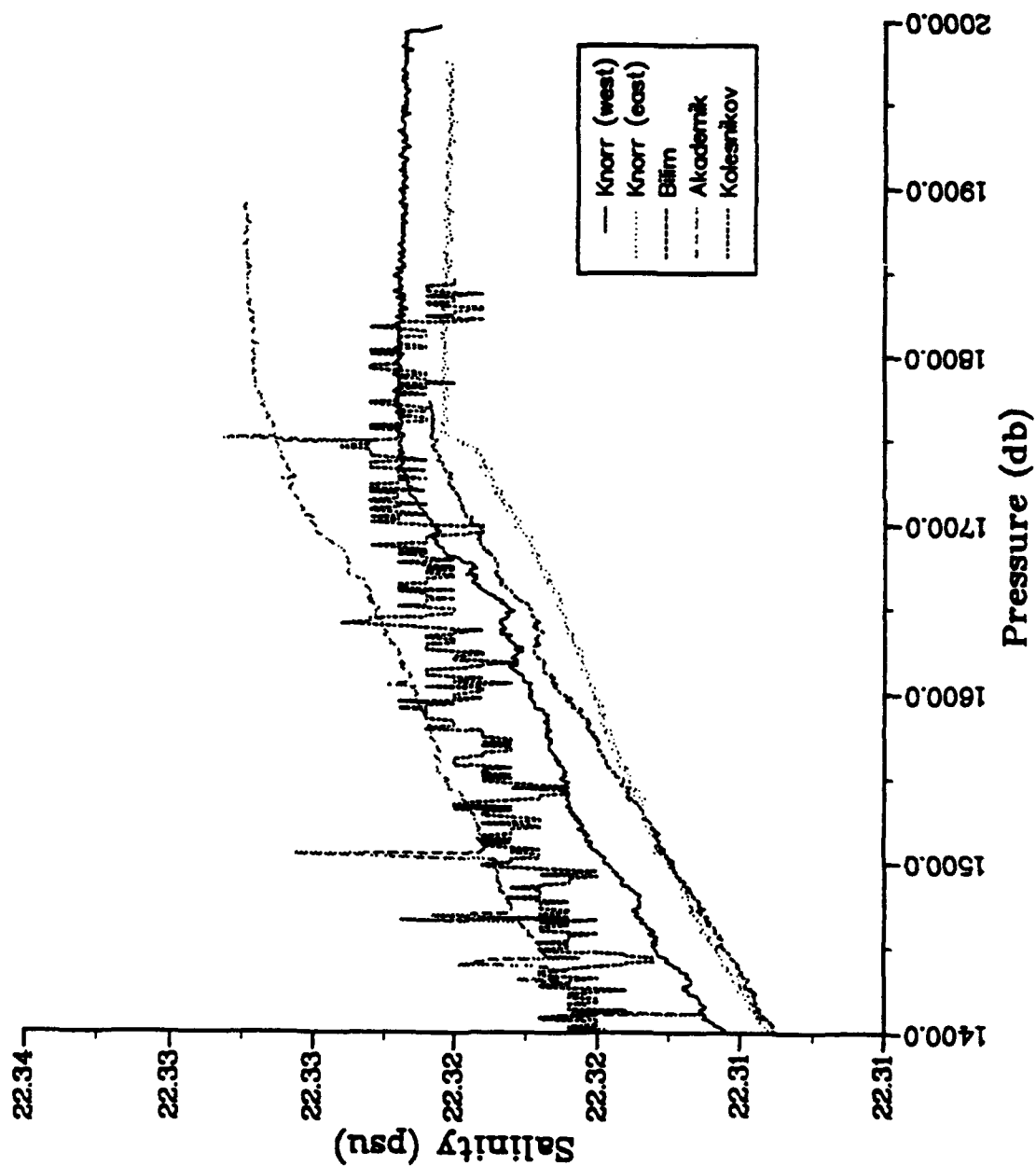


Figure 20: Same data as for Fig. 19, except for a more limited depth range (1400 to 2000 db), and adding the Knorr data. The Bilim data are the closest to the Knorr results; the Akademik CTD data are offset by about 0.01 psu higher compared to the Knorr and Bilim data.

TABLE 3

## STATION CODES AND LOCATIONS

## HYDROBLACK 1991 BLACK SEA CRUISE

## R/V BILIM STATIONS

station	code	lat	long	depth (m)	date	time (GMT)
L50L45	42	41 50 00	29 45 00	2000	09-05-1991	14 10
M10M15	48	42 10 00	30 15 00	2000	09-05-1991	19 35
M50M45	70b	42 50 00	30 45 00	2100	09-06-1991	02 20
N10N15	82b	43 10 00	31 15 00	1800	09-06-1991	06 05
N30N45	101b	43 30 00	31 45 00	1925	09-06-1991	10 50
N10P45	130	43 10 00	32 45 00	2180	09-06-1991	16 20
N10Q15	137	43 10 00	33 15 00	2100	09-06-1991	21 45
M16Q44	151	42 16 00	33 44 00	0900	09-07-1991	17 50
M15Q15	134	42 15 00	33 15 00	1900	09-07-1991	21 25
M30Q15	135	42 30 00	33 15 00	2100	09-07-1991	23 55
M50Q15	136	42 50 00	33 15 00	2100	09-08-1991	03 30
N10Q45	148b	43 10 00	33 45 00	2100	09-08-1991	07 30
M50Q45	149	42 50 00	33 45 00	2100	09-08-1991	11 00
M30Q45	150	42 30 00	33 45 00	2000	09-08-1991	14 10
M30R15	153	42 30 00	34 15 00	2100	09-08-1991	17 30
M16R15	152	42 16 00	34 15 00	0450	09-08-1991	20 10
M19R45	168	42 19 00	34 45 00	1200	09-08-1991	23 00
M14S15	169	42 14 00	35 15 00	2000	09-09-1991	11 00
M30S15	170	42 30 00	35 15 00	2000	09-09-1991	14 20
M32R45	167	42 32 00	34 45 00	2000	09-09-1991	17 40
M50R45	166	42 50 00	34 45 00	2100	09-09-1991	21 30
M50R15	154	42 50 00	34 15 00	2100	09-10-1991	01 20
N10R15	155b	43 10 00	34 15 00	2100	09-10-1991	04 35
N10R45	165	43 10 00	34 45 00	2100	09-10-1991	09 30
N10S15	172	43 10 00	35 15 00	2100	09-10-1991	14 05
N10S45	183	43 10 00	35 45 00	2100	09-10-1991	17 35
N10T15	192	43 10 00	36 15 00	2100	09-10-1991	22 30
N10T45	203	43 10 00	36 45 00	2100	09-11-1991	01 55
M50T45	204	42 50 00	36 45 00	2100	09-11-1991	05 30
M50T15	191	42 50 00	36 15 00	2100	09-11-1991	10 05
M50S45	184	42 50 00	35 45 00	2100	09-11-1991	13 40
M50S15	171	42 50 00	35 15 00	2100	09-11-1991	16 50
M30S45	185	42 30 00	35 15 00	2100	09-11-1991	22 00
M10S45	186	42 10 00	35 45 00	1765	09-12-1991	01 30
M00S56	187	42 00 00	35 56 00	1420	09-12-1991	04 05
M10T15	189	42 10 00	36 15 00	1400	09-12-1991	06 45
M30T15	190	42 30 00	36 15 00	2080	09-12-1991	09 50
M30T45	205	42 30 00	36 45 00	2090	09-12-1991	14 10
M30V15	213	42 30 00	37 15 00	2100	09-12-1991	17 50
M50V15	214	42 50 00	37 15 00	2100	09-12-1991	21 15
M50V45	226b	42 50 00	37 45 00	2100	09-13-1991	00 45
M30W15	236	42 30 00	38 15 00	2100	09-13-1991	06 30
M30V45	227	42 30 00	37 45 00	2100	09-13-1991	09 45
M10V45	228	42 10 00	37 45 00	2100	09-13-1991	13 10
M10V15	212	42 10 00	37 45 00	2000	09-13-1991	16 30
M10T45	206	42 10 00	36 45 00	1800	09-13-1991	21 00
L50T45	207	41 50 00	36 45 00	0560	09-13-1991	23 45
L50V15	211	41 50 00	37 15 00	1930	09-14-1991	02 30

L50V45	229	41 50 00	37 45 00	1900	09-14-1991	06 05
L30V45	230	41 30 00	37 45 00	1850	09-14-1991	09 50
L30W15	233	41 30 00	38 15 00	1960	09-14-1991	13 45
L50W15	234	41 50 00	38 20 00	2000	09-14-1991	17 35
M10W15	235	42 10 00	38 15 00	2100	09-14-1991	20 35
M10W45	248	42 10 00	38 45 00	2100	09-14-1991	23 50
L50W45	249	41 50 00	38 45 00	2050	09-15-1991	03 35
L30W45	250	41 30 00	38 45 00	1950	09-15-1991	06 20
L30X15	253	41 30 00	39 15 00	2000	09-15-1991	10 00
L50X15	254	41 50 00	39 15 00	2020	09-15-1991	13 05
M10X15	255	42 10 00	39 15 00	2050	09-15-1991	16 45
M10X45	266b	42 10 00	39 45 00	2050	09-15-1991	19 50
L50X45	267	41 50 00	39 45 00	1960	09-16-1991	00 15
L30X45	268	41 30 00	39 45 00	1950	09-16-1991	03 10
L30Y15	271	41 30 00	40 15 00	1770	09-16-1991	07 50
L50Y15	272	41 50 00	40 15 00	1850	09-16-1991	11 30
L50Y45	281	41 50 00	40 15 00	1650	09-16-1991	15 50
L30Y50	282	41 30 00	40 50 00	1660	09-16-1991	18 35
L15Y45	283	41 15 00	40 45 00	1380	09-16-1991	22 15
L15Y15	270	41 15 00	40 15 00	1630	09-17-1991	01 25
L15X45	269	41 15 00	39 45 00	1780	09-17-1991	05 35
L15X15	252	41 15 00	39 15 00	1460	09-17-1991	08 40
L15W45	251	41 15 00	38 45 00	1660	09-17-1991	12 20
L15W15	232	41 15 00	38 15 00	1460	09-17-1991	15 40
L15V45	231	41 15 00	37 45 00	1470	09-17-1991	18 50
L31V22	209	41 31 00	37 22 00	1580	09-17-1991	21 05
L35T45	208	41 35 00	36 45 00	0500	09-18-1991	02 45
L45T15	188	41 45 00	36 15 00	0920	09-18-1991	05 40
M10P45	133	42 10 00	32 45 00	2100	09-19-1991	10 00
M30P45	132	42 30 00	32 45 00	2100	09-19-1991	13 00
M50P45	131	42 50 00	32 45 00	2100	09-19-1991	16 00
M50P15	111	42 50 00	32 15 00	2100	09-19-1991	19 30
N10P15	112	43 10 00	32 15 00	2100	09-19-1991	22 20
N10N45	102	43 10 00	31 45 00	2100	09-20-1991	01 40
M50N45	103	42 50 00	31 45 00	2100	09-20-1991	04 30
M30N45	104	42 30 00	31 45 00	2100	09-20-1991	08 20
M30P15	110	42 30 00	32 15 00	2100	09-20-1991	11 45
M10P15	109	42 10 00	32 15 00	2100	09-20-1991	14 40
M10N45	105	42 10 00	31 45 00	2100	09-20-1991	18 50
L50N45	106	41 50 00	31 45 00	1630	09-20-1991	21 40
L50N15	78	41 50 00	31 15 00	2030	09-21-1991	01 25
M10N15	79	42 10 00	31 15 00	2100	09-21-1991	05 10
M30N15	80	42 30 00	31 15 00	2100	09-21-1991	08 35
M30M45	71	42 30 00	30 45 00	2100	09-21-1991	12 30
M10M45	72	42 10 00	30 45 00	2100	09-21-1991	15 50
L50M45	73	41 50 00	30 45 00	1900	09-21-1991	19 35
L30N15	77	41 30 00	31 15 00	1450	09-21-1991	23 45
L30M45	74	41 30 00	30 45 00	1400	09-22-1991	03 15
L15M40	75	41 15 00	30 40 00	1100	09-22-1991	05 30
L21M20	45	41 21 00	30 20 00	0100	09-22-1991	08 10
L32M13	46	41 32 00	30 13 00	1000	09-22-1991	09 30
L50M15	47	41 50 00	30 15 00	1980	09-22-1991	12 10
M10L45	41	42 10 00	29 45 00	2150	09-22-1991	17 25
L50L45	42	41 50 00	29 45 00	2000	09-22-1991	20 55

L30L45	43	41 30 00	29 45 00	1500	09-23-1991	00 50
L25L30	44	41 25 00	29 30 00	0600	09-23-1991	03 00

### R/V K. PIRI REIS STATIONS

station	code	lat	long	depth	date	time
L18L15	22	41 18 00	29 15 00	0080	09-07-1991	10 10
L30L15	23	41 30 00	29 15 00	0365	09-07-1991	14 00
L50K20	7	41 50 00	28 20 00	0070	09-07-1991	17 00
M10K20	8r	42 10 00	28 20 00	0100	09-07-1991	21 00
M10K45	20	42 10 00	28 45 00	0600	09-07-1991	23 30
L50K45	21	41 50 00	28 45 00	0400	09-08-1991	02 30
L50L15	24	41 50 00	29 15 00	1748	09-12-1991	14 15
M10L15	25	42 10 00	29 15 00	1924	09-12-1991	19 15
M30L15	26r	42 30 00	29 15 00	1976	09-12-1991	23 55
M30L45	40r	42 30 00	29 45 00	2106	09-13-1991	05 15
M30M15	49	42 30 00	30 15 00	2109	09-13-1991	11 15
M50M15	50r	42 50 00	30 15 00	2097	09-13-1991	14 45
M50N15	81	42 50 00	31 15 00	2094	09-13-1991	23 35
L15N15	76	41 15 00	31 15 00	0088	09-15-1991	11 45
L35N45	107	41 35 00	31 45 00	2000	09-16-1991	09 20
L50P15	108	41 50 00	32 15 00	2000	09-17-1991	13 35

### R/V KOLESNIKOV STATIONS

station	code	lat	long	depth	date	time
M50V45	226k	42 50 00	37 45 00	2150	09-09-1991	15 30
M50W15	237	42 50 00	38 15 00	2135	09-09-1991	19 15
M50W45	246	42 50 00	38 45 00	2110	09-09-1991	22 15
M30W45	247	42 30 00	38 45 00	2100	09-10-1991	02 00
M30X15	256	42 30 00	39 15 00	2050	09-10-1991	05 40
M30X45	265	42 30 00	39 45 00	1950	09-10-1991	08 55
M10X45	266k	42 10 00	39 45 00	1970	09-10-1991	12 30
M10Y15	273	42 10 00	40 15 00	1870	09-10-1991	15 40
M10Y45	280	42 10 00	40 45 00	1565	09-10-1991	18 35
L50Z15	284	41 50 00	41 15 00	1180	09-10-1991	22 55
M10Z15	285	42 10 00	41 15 00	1185	09-11-1991	01 40
M30Z15	286	42 30 00	41 15 00	0700	09-11-1991	04 40
M40Z00	287	42 40 00	41 00 00	1275	09-11-1991	07 10
M30Y45	279	42 30 00	40 45 00	1600	09-11-1991	09 25
M30Y15	274	42 30 00	40 15 00	1590	09-11-1991	13 05
M50Y45	278	42 50 00	40 45 00	1040	09-11-1991	18 00
M50Y15	275	42 50 00	40 15 00	0995	09-11-1991	20 45
N03Y03	277	43 03 00	40 03 00	1400	09-11-1991	23 05
N10X45	263	43 10 00	39 45 00	1530	09-12-1991	01 20
M50X45	264	42 50 00	39 45 00	1880	09-12-1991	05 25
M50X15	257	42 50 00	39 15 00	2000	09-12-1991	09 10
N10X15	258	43 10 00	39 15 00	1900	09-12-1991	11 45
N24X35	261	43 24 00	39 35 00	1370	09-12-1991	15 25
N30X15	259	43 30 00	39 15 00	1840	09-12-1991	18 50
N45X08	260	43 45 00	39 08 00	1050	09-12-1991	21 00

N30W45	244	43 30 00	38 45 00	2120	09-13-1991	00 20
N50W45	243	43 50 00	38 45 00	1740	09-13-1991	03 30
P05W37	242	44 05 00	38 37 00	1225	09-13-1991	06 00
P10W15	241	44 10 00	38 15 00	1790	09-13-1991	09 10
N50W15	240	43 50 00	38 15 00	2130	09-13-1991	12 25
N30W15	239	43 30 00	38 15 00	2144	09-13-1991	16 10
N10W45	245	43 10 00	38 45 00	2120	09-13-1991	21 25
N10W15	238	43 10 00	38 15 00	2140	09-14-1991	00 10
N30V45	224	43 30 00	37 45 00	2150	09-14-1991	04 30
N10V45	225	43 10 00	37 45 00	2160	09-14-1991	07 35
N10V15	215	43 10 00	37 15 00	2170	09-14-1991	11 15
N30V15	216	43 30 00	37 15 00	2165	09-14-1991	15 00
N50V45	223	43 50 00	37 45 00	2140	09-14-1991	18 30
N50V15	217	43 50 00	37 15 00	2130	09-14-1991	22 00
N50T45	201	43 50 00	36 45 00	0214	09-15-1991	01 10
N30T45	202	43 30 00	36 45 00	2175	09-15-1991	04 35
N30T15	193	43 30 00	36 15 00	2000	09-15-1991	08 50
N50T15	194	43 50 00	36 15 00	2000	09-15-1991	12 30
P10T45	200	44 10 00	36 45 00	1965	09-15-1991	19 25
P10V15	218	44 10 00	37 15 00	2000	09-15-1991	23 40
P10V45	222	44 10 00	37 45 00	0920	09-16-1991	03 40
P28V45	221	44 28 00	37 45 00	1780	09-16-1991	06 50
P30V15	219	44 30 00	37 15 00	1150	09-16-1991	09 45
P45V05	220	44 45 00	37 05 00	0810	09-16-1991	12 50
P50T45	198	44 50 00	36 45 00	0062	09-16-1991	14 45
P30T45	199	44 30 00	36 45 00	0990	09-16-1991	18 05
P10T15	195	44 10 00	36 15 00	1700	09-16-1991	21 50
P30T15	196	44 30 00	36 15 00	0750	09-17-1991	01 15
P50T15	197	44 50 00	36 15 00	0080	09-17-1991	04 05
P42S45	178	44 42 00	35 45 00	0600	09-17-1991	06 55
P30S45	179	44 30 00	35 45 00	1300	09-17-1991	09 20
P10S45	180	44 10 00	35 45 00	1890	09-17-1991	12 45
N50S45	181	43 50 00	35 45 00	2100	09-17-1991	15 15
N30S45	182	43 30 00	35 45 00	2200	09-17-1991	19 00
N30S15	173	43 30 00	35 15 00	2200	09-17-1991	22 25
N50S15	174	43 50 00	35 15 00	2200	09-18-1991	01 30
P10S15	175	44 10 00	35 15 00	2100	09-18-1991	04 10
P41S15	177	44 41 00	35 15 00	0730	09-18-1991	09 05
P36R45	160	44 36 00	34 45 00	1360	09-18-1991	12 00
P10R45	162	44 10 00	34 45 00	2160	09-18-1991	16 00
P15R15	158	44 15 00	34 15 00	1270	09-18-1991	20 10
N50R15	157	43 50 00	34 15 00	2140	09-19-1991	00 05
N50R45	164	43 50 00	34 45 00	2205	09-19-1991	03 10
N30R45	163	43 30 00	34 45 00	2210	09-19-1991	06 20
N10R15	155k	43 10 00	34 15 00	2215	09-19-1991	10 35
N10Q45	148k	43 10 00	33 45 00	2220	09-19-1991	13 55
N30R15	156	43 30 00	34 15 00	2220	09-19-1991	18 00
N30Q45	147	43 30 00	33 45 00	2190	09-19-1991	21 30
N50Q45	146	43 50 00	33 45 00	2100	09-20-1991	00 30
N50Q15	139	43 50 00	33 15 00	2000	09-20-1991	04 00
P10Q15	140	44 10 00	33 15 00	1890	09-20-1991	07 00
P25Q08	141	44 25 00	33 08 00	0670	09-20-1991	10 00
P07Q45	145	44 07 00	33 45 00	0955	09-20-1991	17 40
N30Q15	138	43 30 00	33 15 00	2180	09-20-1991	21 25

N30P45	129	43 30 00	32 45 00	2130	09-21-1991	04 00
N50P45	128	43 50 00	32 45 00	1925	09-21-1991	07 40
N50P15	114	43 50 00	32 15 00	1800	09-21-1991	11 15
N30P15	113	43 30 00	32 15 00	2000	09-21-1991	14 30
N30N45	101k	43 30 00	31 45 00	1915	09-21-1991	18 00
N50N45	100k	43 50 00	31 45 00	1635	09-21-1991	20 40
N50N15	84k	43 50 00	31 15 00	1660	09-21-1991	23 45
N30N15	83k	43 30 00	31 15 00	1615	09-22-1991	03 10
P30P45	126k	44 30 00	32 45 00	1500	09-28-1991	21 30
P10P45	127	44 10 00	32 45 00	1750	09-29-1991	01 00
P10P15	115	44 10 00	32 15 00	1595	09-29-1991	03 40
P30P15	116k	44 30 00	32 15 00	1415	09-29-1991	07 00
P30N45	98k	44 30 00	31 45 00	1190	09-29-1991	10 00
P10N45	99k	44 10 00	31 45 00	1200	09-29-1991	13 15
P10N15	85k	44 10 00	31 15 00	0750	09-29-1991	16 40

### R/V AKADEMIK STATIONS

station	code	lat	long	depth	date	time
N10K05	3	43 45 00	28 05 00	0020	09-03-1991	13 00
N10K20	11	43 10 00	28 20 00	0040	09-03-1991	16 26
N10K50	17	43 10 00	28 50 00	0325	09-03-1991	21 10
N10L15	28	43 10 00	29 15 00	1640	09-04-1991	02 12
N10L45	38	43 10 00	29 45 00	1600	09-04-1991	06 45
N10M15	51	43 10 00	30 15 00	1743	09-04-1991	10 50
N10M45	69	43 10 00	30 45 00	1945	09-04-1991	15 05
N10N15	82a	43 10 00	31 15 00	1804	09-04-1991	19 05
N30N45	101a	43 30 00	31 45 00	1927	09-05-1991	01 55
N30N15	83a	43 30 00	31 15 00	1600	09-05-1991	06 30
N30M45	68	43 30 00	30 45 00	1400	09-05-1991	11 30
N30M15	52	43 30 00	30 15 00	1300	09-05-1991	15 50
N30L45	37	43 30 00	29 45 00	0820	09-05-1991	20 50
N30L15	29	43 30 00	29 15 00	0091	09-06-1991	02 00
N30K50	16	43 30 00	28 50 00	0074	09-06-1991	06 10
N30K40	12	43 30 00	28 40 00	0065	09-06-1991	10 50
M50K20	10	42 50 00	28 20 00	0092	09-06-1991	19 00
M40J50	1	42 40 00	27 50 00	0022	09-06-1991	22 03
M30K05	6	42 30 00	28 05 00	0066	09-07-1991	01 15
M50K05	5	42 50 00	28 05 00	0037	09-07-1991	05 35
M10K20	8a	42 10 00	28 20 00	0105	09-07-1991	11 30
M30K20	9	42 30 00	28 20 00	0098	09-07-1991	15 45
M30K45	19	42 30 00	28 45 00	1390	09-07-1990	18 50
M50K45	18	42 50 00	28 45 00	1160	09-07-1990	23 45
M50L15	27	42 50 00	29 15 00	2036	09-08-1991	03 20
M30L15	26a	42 30 00	29 15 00	2020	09-08-1991	06 50
M30L45	40a	42 30 00	29 45 00	2160	09-08-1991	12 00
M50L45	39	42 50 00	29 45 00	2110	09-08-1991	15 10
M50M15	50a	42 50 00	30 15 00	2150	09-08-1991	20 35
M50M45	70a	42 50 00	30 45 00	2160	09-09-1991	00 15
N50N15	84a	43 50 00	31 15 00	1590	09-09-1991	09 35
P10N15	85a	44 10 00	31 15 00	0721	09-09-1991	16 15
P30N15	86a	44 30 00	31 15 00	0600	09-09-1991	22 10



P50N15	87a	44 50 00	31 15 00	0066	09-10-1991	02 45
P50M45	64a	44 50 00	30 45 00	0066	09-10-1991	05 30
P30M45	65	44 30 00	30 45 00	0097	09-10-1991	07 50
P10M45	66	44 10 00	30 45 00	0126	09-10-1991	11 30
N50M45	67	43 50 00	30 45 00	1020	09-10-1991	14 50
N50M15	53	43 50 00	30 15 00	0116	09-10-1991	18 45
P10M15	54	44 10 00	30 15 00	0094	09-10-1991	20 00
P30M15	55	44 30 00	30 15 00	0072	09-10-1991	22 45
P50M15	56a	44 50 00	30 15 00	0050	09-11-1991	03 15
P50M00	33	44 50 00	30 00 00	0044	09-11-1991	05 25
P30L45	34	44 30 00	29 45 00	0059	09-11-1991	07 50
P10L00	14	44 10 00	29 00 00	0042	09-11-1991	13 00
P10L15	31	44 10 00	29 15 00	0051	09-11-1991	15 35
P10L45	35	44 10 00	29 45 00	0063	09-11-1991	19 00
N50L45	36	43 50 00	29 45 00	0074	09-11-1991	21 50
N50L15	30	43 50 00	29 15 00	0064	09-12-1991	00 05
N40K55	15	43 40 00	28 55 00	0058	09-12-1991	03 35
N39K36	13	43 39 00	28 36 00	0012	09-12-1991	06 25
N10K12	4	43 10 00	28 12 00	0025	09-12-1991	13 30
N10K02	2	43 10 00	28 02 00	0015	09-12-1991	15 05

# R/V PARSHIN STATIONS

station	code	lat	long	depth	date	time
R30N15	92	46 30 00	31 15 00	0008	09-08-1991	21 10
R10M45	60	46 10 00	30 45 00	0020	09-08-1991	00 10
Q50M22	59	45 50 00	30 22 00	0017	09-08-1991	03 20
Q30M15	58	45 30 00	30 15 00	0025	09-08-1991	05 39
Q10M15	57	45 10 00	30 15 00	0024	09-08-1991	07 50
P50M15	56p	44 50 00	30 15 00	0045	09-08-1991	10 15
P50M15	64p	44 50 00	30 15 00	0062	09-08-1991	12 45
Q10M45	63	45 10 00	30 45 00	0040	09-08-1991	15 20
Q30M45	62	45 30 00	30 45 00	0037	09-08-1991	17 40
Q50M45	61	45 50 00	30 45 00	0016	09-08-1991	20 16
R10N15	91	46 10 00	31 15 00	0024	09-08-1991	23 10
Q50N15	90	45 50 00	31 15 00	0021	09-09-1991	01 10
Q30N15	89	45 30 00	31 15 00	0041	09-09-1991	03 20
Q10N15	88	45 10 00	31 15 00	0052	09-09-1991	05 40
P50N15	87p	44 50 00	31 14 00	0063	09-09-1991	07 45
P30N15	86p	44 30 00	31 15 00	0620	09-09-1991	10 10
P10N15	85p	44 10 00	31 15 00	0760	09-09-1991	18 00
N50N15	84p	43 50 00	31 15 00	1470	09-09-1991	22 10
N30N15	83p	43 30 00	31 15 00	1600	09-10-1991	02 40
N30N45	101p	43 30 00	31 45 00	1926	09-10-1991	08 35
N52N40	100p	43 52 00	31 40 00	1500	09-10-1991	15 00
P12N44	99p	44 12 00	31 44 00	1220	09-10-1991	22 00
P30N45	98p	44 30 00	31 45 00	1090	09-11-1991	02 55
P49N44	97	44 49 00	31 44 00	0059	09-11-1991	06 45
Q10N45	96	45 10 00	31 45 00	0051	09-11-1991	09 00
Q30N45	95	45 30 00	31 45 00	0044	09-11-1991	11 15
Q50N46	94	45 50 00	31 46 00	0027	09-11-1001	13 30
R08N45	93	46 08 00	31 45 00	0009	09-11-1991	15 30

R05P16	122	46 05 00	32 16 00	0008	09-11-1991	17 45
Q50P45	123	45 50 00	32 45 00	0022	09-11-1991	20 15
Q49P15	121	45 49 00	32 15 00	0026	09-11-1991	22 15
Q30P15	120	45 30 00	32 15 00	0035	09-12-1991	00 19
Q10P15	119	45 10 00	32 15 00	0048	09-12-1991	02 30
Q00P16	118	44 00 00	32 16 00	0075	09-12-1991	03 50
P30P15	116p	44 30 00	32 15 00	1380	09-12-1991	06 45
P31P45	126p	44 31 00	32 45 00	0780	09-12-1991	11 10
P50P45	125	44 50 00	32 45 00	0130	09-12-1991	13 40
P49Q16	142	44 49 00	33 16 00	0092	09-12-1991	16 05
Q05Q15	143	45 05 00	33 15 00	0022	09-12-1991	17 55
Q10P45	124	45 10 00	32 45 00	0070	09-12-1991	20 15

**Akademik data:** The Akademik data were in good condition, except for some spikes noted at greater depths due to cable noise. These data were filtered in both temperature and conductivity. Although instead of filtering, the data could have been corrected by examining the modulo count and discarding any count increments greater than 24, the latter procedure would have been too time consuming for the small amplitude of spikes experienced. Butterworth filtering was effective at removing the spikes.

The shallow water spikes arising from ship motions influencing the seasonal thermocline were not removed. Their removal requires analysis of raw data, which was too time-consuming. These spikes will have to be removed at a later date.

**Bilim data:** These data were essentially noise-free, and hence were not filtered.

**Kolesnikov data:** These data were much noisier than the Akademik and Bilim data. Several types of filtering and corrections were made to these data.

The temperature data were examined in detail, and found to have large staircases (temperature sticking at a single value for up to 50 db). Although double-diffusion might provide similar ramps, they would not be expected to be of the same vertical scale, and would be seen in the other data (SBE-9), where they were absent. This staircase therefore was judged to be a faulty thermistor. To correct this error, the most prominent ramps (the largest at 9.015 degrees) were filtered by applying a linear correction over the length of this ramp. To filter out other staircases and to smooth out the discretization ramps, the temperature data were subjected below 500 db to a tenth order low-pass Butterworth filter, with a cutoff frequency at 0.05 per meter.

The conductivity data were fairly smooth, except for ripples having spatial scales of about 20-50 m, and amplitudes of about 0.01 mhos/m. Though smooth, the same filter was applied to these data to match that applied to the temperature data. In addition, the conductivity data also flattened out at great depths, compared to the Akademik and Bilim data (e.g., Figure 19). To correct for this effect, the depth-dependent correction that the Kolesnikov scientists applied to the data was removed, using the formula:

$$C_n = C_m / (1 + C_{kp} * p)$$

where the subscript n refers to the adjusted value, C is conductivity, m is the measured value,  $C_{kp}$  is the conductivity depth coefficient, and p is pressure in db. The Kolesnikov used a value of  $5 \times 10^{-5}$  for  $C_{kp}$ . To investigate the effect of  $C_{kp}$  on the slope of the conductivity data at depth, various values of  $C_{kp}$  were applied to the conductivity data after the correction was removed ( $C_{kp}=0$ ). The values for  $C_{kp}$  used were  $1.5 \times 10^{-5}$ ,  $2.5 \times 10^{-5}$ , and  $3.5 \times 10^{-5}$ . Using several intercalibration stations with the Kolesnikov (including M10X45 and N30N45), the least error at depth occurred for values of about  $1.5 \times 10^{-5}$  for  $C_{kp}$  (Figures 21 and 22). This empirical depth dependency was derived for shallower water, but apparently was not optimized in deeper waters where the effect is greatest and where the intercalibration took place.

**Parshin:** No corrections or filtering were made to the Parshin data, because there were inadequate data with which to intercompare quantitatively. Intercomparison at one intercalibration station (Figure 23) shows the coarseness of the Parshin sampling, making detailed comparison impossible. Since the Parshin data are used only in shallow water where dynamic range is great, the lack of intercalibration is not limiting.

**Piri Reis:** The Piri Reis data were similar to the Bilim's, and required no filtering or spike removal.

# M10X45 Koles. & Bilim Salinity

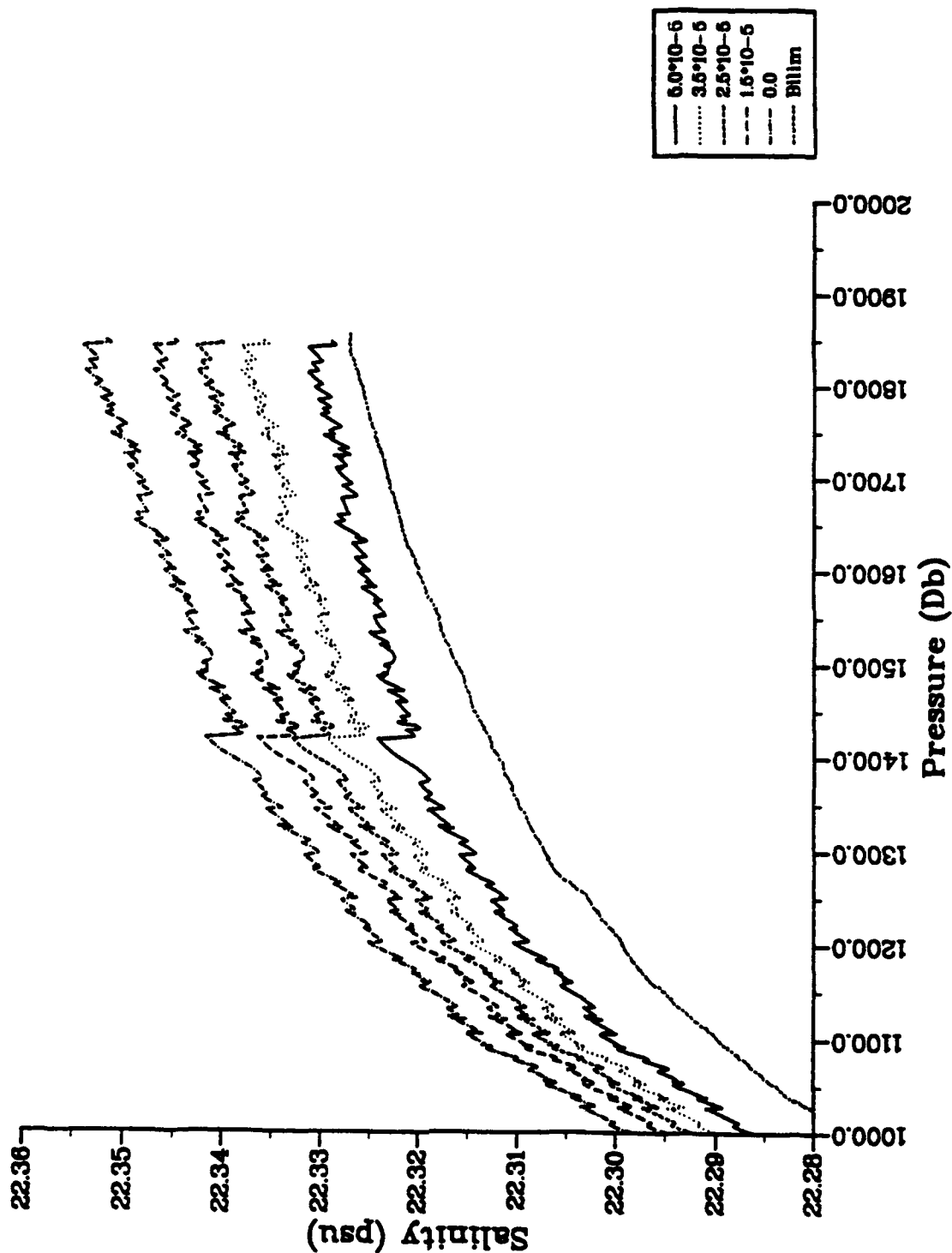


Figure 21: Comparison of salinity for the Kolesnikov and Bilim at station M10X45, varying the depth-dependent conductivity correction for the Kolesnikov CTD. The effect of the correction on the flattening of the salinity data at depth is shown.

## M10X45 Koles.-Bilim Conductivity Differences

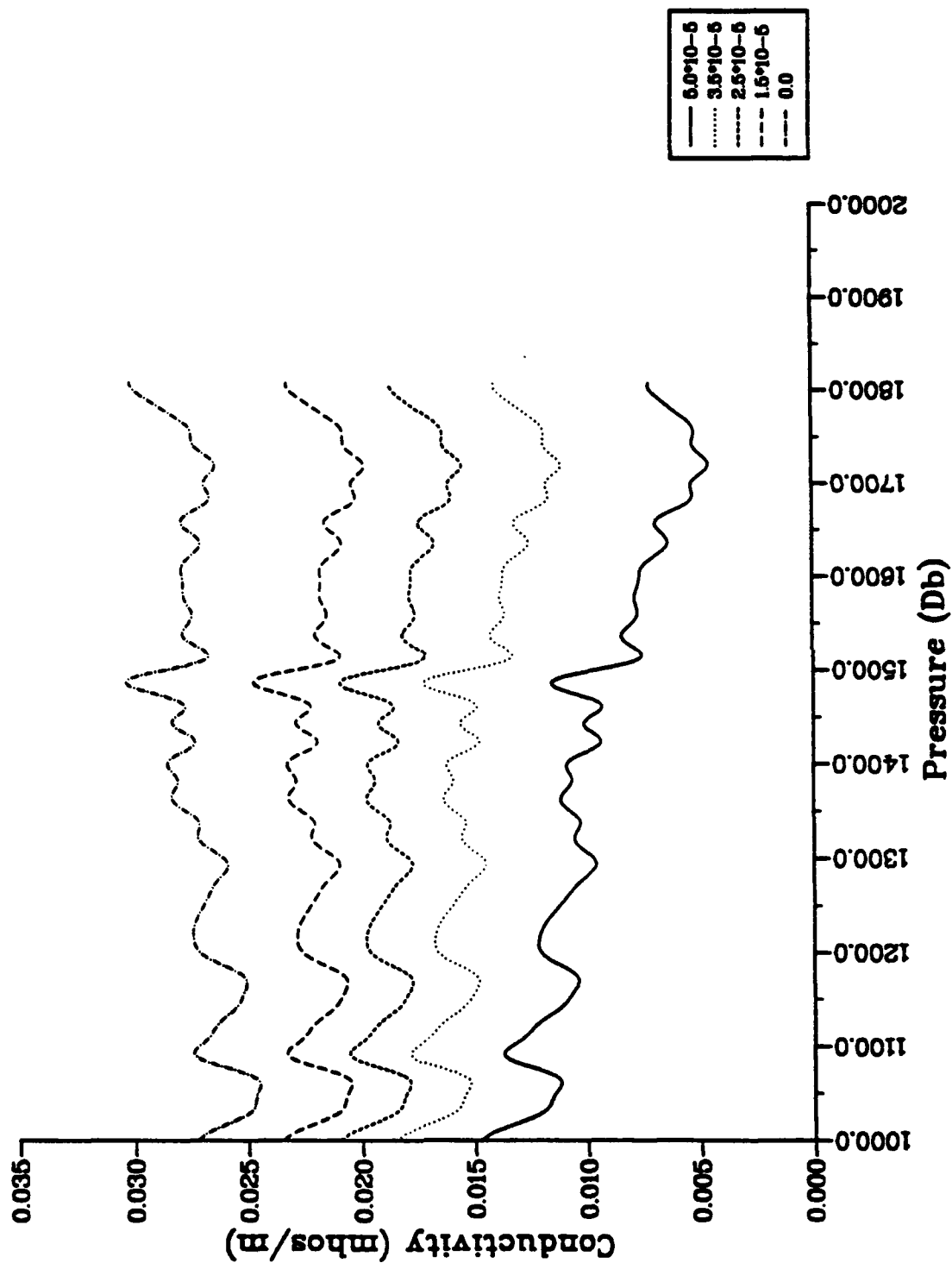


Figure 22: Differences in conductivities for the Kolesnikov and the Bilim at station M10X45, varying the depth-dependent conductivity correction for the Kolesnikov CTD. Although offsets are found in all sets, the error has no depth dependence for the case of the smallest depth correction.

## N30N45 Parshin Intercalibration

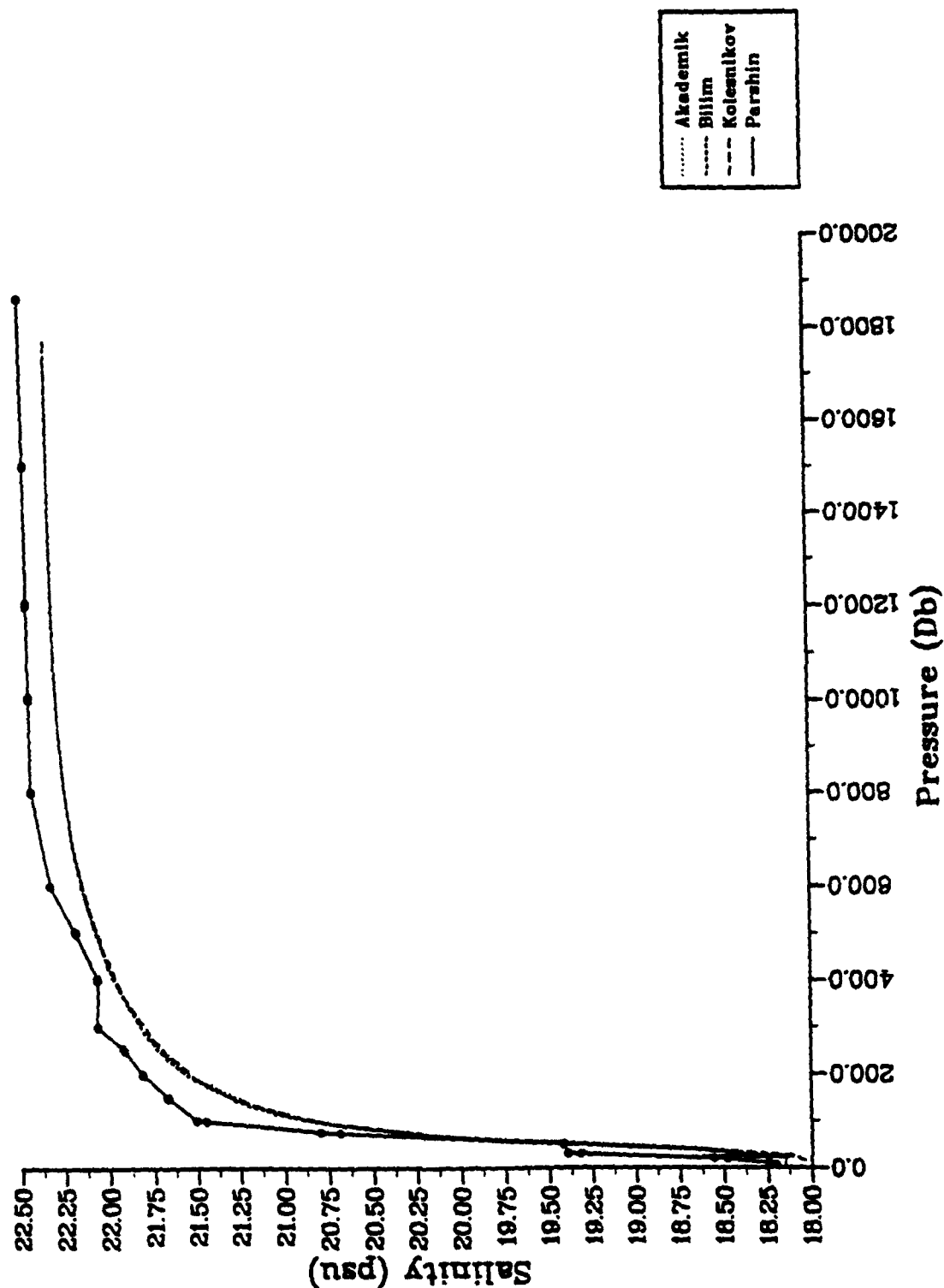


Figure 23: Intercomparison of the Parshin salinity data with Akademik, Bilim, and Kolesnikov data at station N30N45. Data points for the Parshin are shown as circles, indicating the coarseness of the sampling. Data points for other CTD's are not shown, since the sampling interval was too small. The coarseness of the Parshin data indicates that detailed intercalibration is impossible. Note that at this coarse depth scale, the three other ships produced data that are indistinguishable. Since most of the Parshin data are from shallow stations, this coarse sampling is less damaging.

**TEMPERATURE CORRECTIONS:** The filtered and de-spiked data were compared then compared to provide intercalibration offsets for all instruments for temperature. For temperature, corrections were derived from comparison at numerous intercalibration stations (Table 4). Based on these comparisons, the Bilim, Piri Reis, and Akademik temperatures were kept constant. The Kolesnikov temperature was reduced by  $0.01^{\circ}\text{C}$ , although the scatter about this value is about  $0.005^{\circ}\text{C}$ . Lack of a clear time variation in temperature offset precluded more accurate correction.

**CONDUCTIVITY CORRECTIONS:** The filtered and de-spiked data were then compared to provide intercalibration offsets for all instruments. Offsets were applied only to bin-averaged temperature and conductivity, not to salinity. For conductivity, the corrections were made after comparisons shown in Table 5. Since Bilim and Akademik conductivities were nearly equal (within approximately  $0.005\text{ S/m}$  of each other), the other gauges were intercalibrated to these. The Kolesnikov conductivity was reduced by  $0.023\text{ S/m}$  to provide best agreement and the Piri Reis was reduced by  $0.01\text{ S/m}$ . The Akademik conductivity was reduced by  $0.006\text{ S/m}$ , which is close to the accuracy of the present data.

**INTERCALIBRATED DATA:** After application of the conductivity and temperature filtering and offsets, the new salinity was computed. Also computed were potential temperature ( $\Theta$ ) and potential density ( $\sigma_{\theta}$ ). Some examples of the intercomparisons of conductivity and salinity following these corrections are presented as Figures 24 through 35. For many of the intercalibration stations, the difference in intercalibrated temperatures is of the order of  $0.005^{\circ}\text{C}$ , and the salinity is  $0.003\text{ psu}$  (e.g., Figures 24 and 25). For other stations, some difference in structure is apparent (e.g., Figure 26 of potential temperature), which is due to slight differences of position of the ships which in turn measure different thickness of bml. Other differences in temperature are as high as  $0.005^{\circ}\text{C}$ , such as in Figure 28. Finally, the greatest differences occur in intercomparisons with the Kolesnikov, which experienced significant drift in temperature (plus or minus  $0.01^{\circ}\text{C}$ ). Comparisons between the Kolesnikov data and the Bilim or Akademik data show little consistency, with Kolesnikov salinity either above or below that at the other ships, depending on the date and location. Since no simple time variability to temperature changes was noted, no better correction could be added. Hence, the uncertainty in the measurements for the Kolesnikov is about  $0.01^{\circ}\text{C}$ . However, at some stations, the Akademik, Kolesnikov, and Bilim agree well, such as at Station N30N45 (Figures 34 and 35). Here, the agreement in temperature is better than  $0.005^{\circ}\text{C}$ , and the agreement in salinity is within  $0.004\text{ psu}$  in general.

**SALINITY BOTTLE SAMPLES FOR TITRATION:** Water samples were obtained at each cast aboard the ships. These bottle samples were intended for intercalibration purposes. However, the sampling procedure was flawed in that the cruise plan did not specify the type of bottle to be used, nor the depths at which samples were to be taken. Consequently, the data from the Turkish ships and the Bulgarian ship had to be discarded. The bottles used were made of plastic, and evaporation occurred in the bottles before their analysis at Woods Hole.

The samples taken aboard the Parshin and the Kolesnikov were made with standard glass bottles, and hence were of high quality except when the sampling rosette leaked. However, the Parshin samples were taken at shallow depths where variability is high, and hence were of no use in intercalibration between ships. The Kolesnikov data were the best of the group (Table 6). In general, the bottle samples disagreed with the Kolesnikov conductivity measured by the Istok CTD by about  $0.025\text{ S/m}$ . This value is about  $0.008\text{ S/m}$  less than that applied based on intercomparison of the profiles at intercalibration stations. This difference is consistent with the uncertainty resulting from the temperature drift.

## N10N15 Final Intercomparison

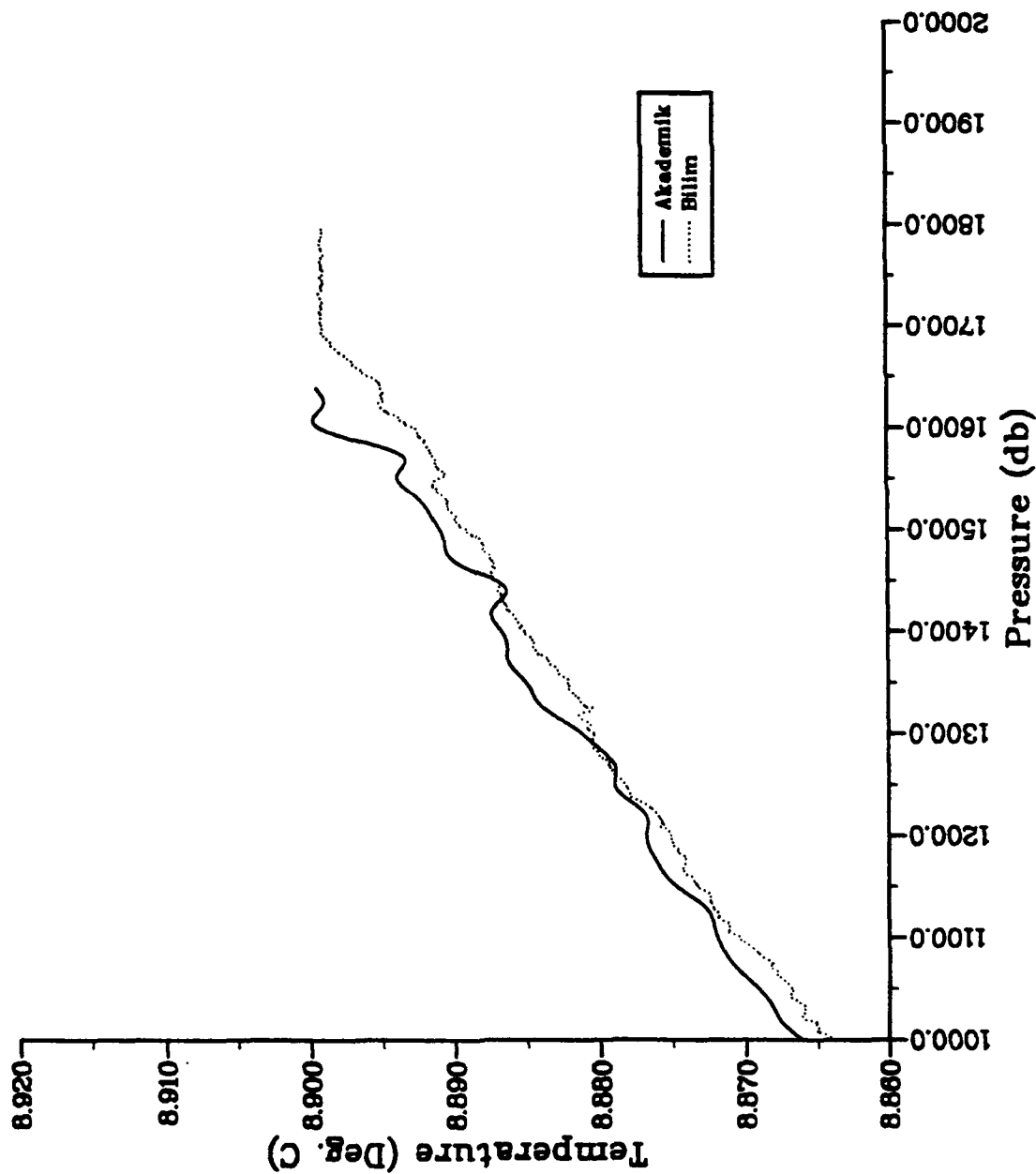


Figure 24: After intercalibration, the temperature data for the Akademik and the Bilim are approximately overlying at station N10N15. The low-frequency wiggles in the Akademik data are due to spiking and the effects of the low-pass filter. The temperatures are within 0.003°C or less throughout this depth range.



## N10N15 Final Intercomparison

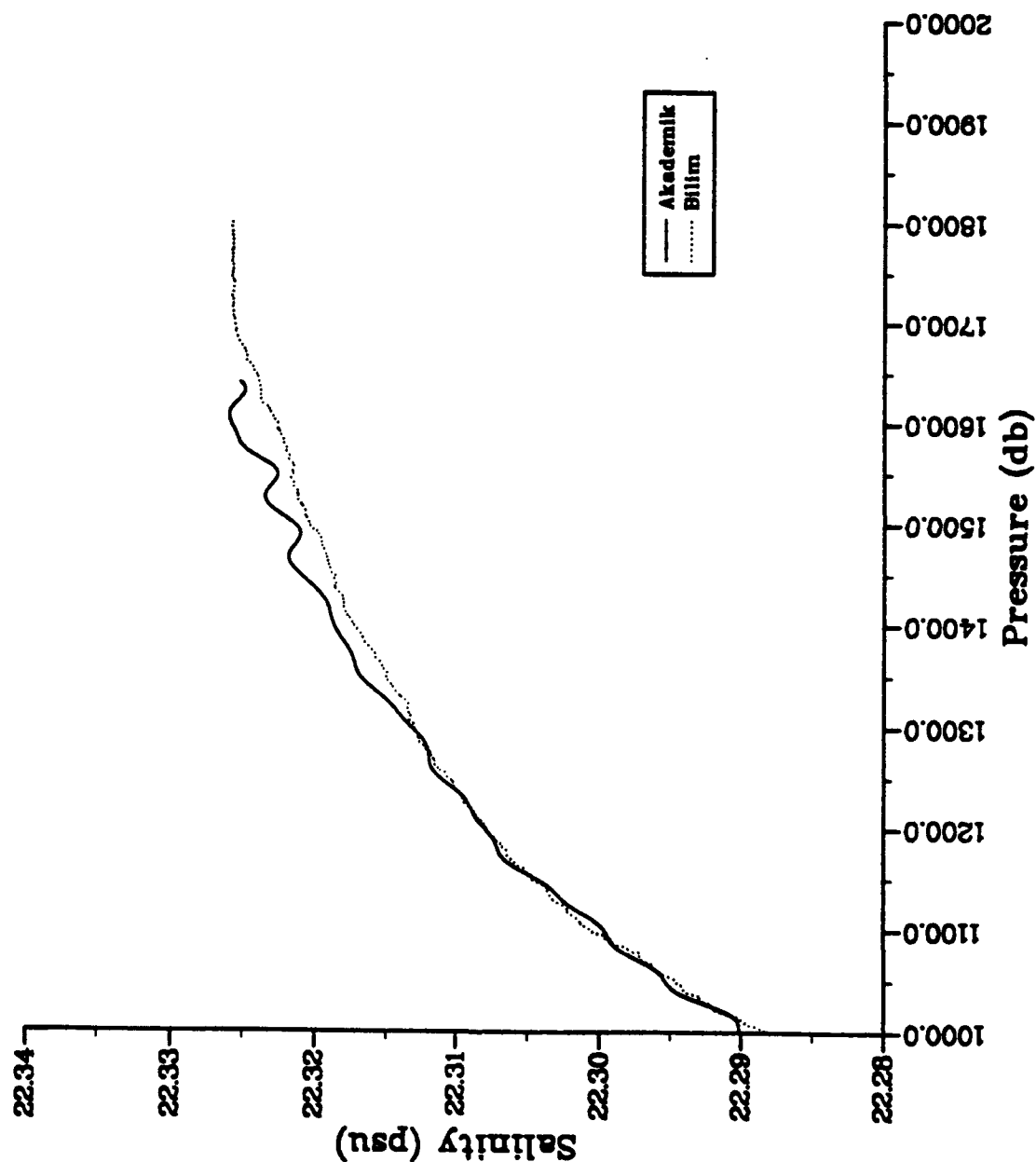


Figure 25: After intercalibration, the salinity data for the Akademik and the Bilim are approximately overlying at station N10N15. The low-frequency wiggles in the Akademik data are due to spiking in temperature and the effects of the low-pass filter. The salinities are within 0.003 psu or less throughout this depth range.

## M50M45 Final Intercomparison

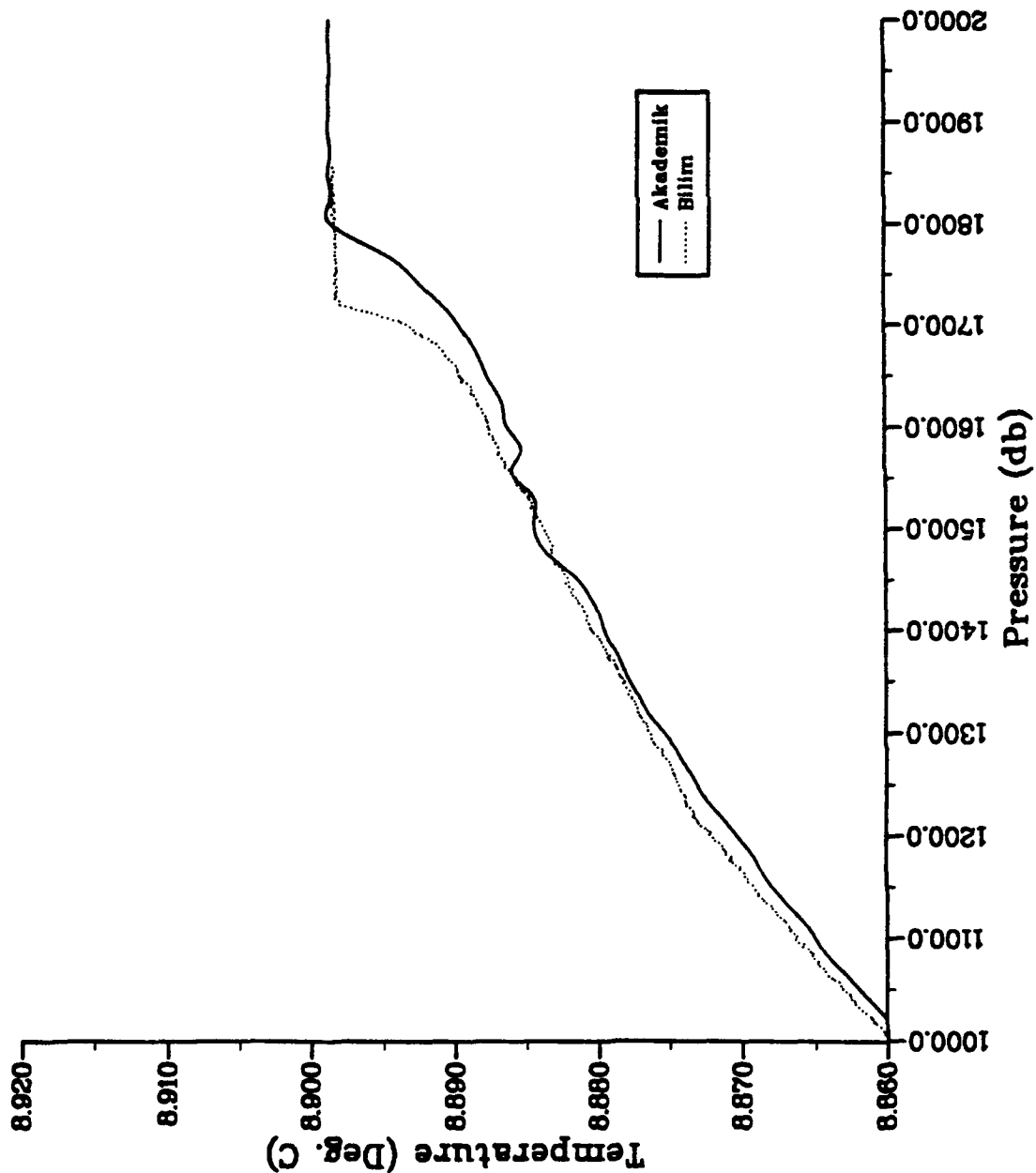


Figure 26: After intercalibration, the temperature data for the Akademik and the Bilim are approximately overlying at station M50M45. The low-frequency wiggles in the Akademik data are due to spiking and the effects of the low-pass filter. The temperatures are within  $0.003^{\circ}\text{C}$  or less over this depth range, and the temperatures in the bottom mixed layer differ by less than  $0.001^{\circ}\text{C}$ .

## M50M45 Final Intercomparison

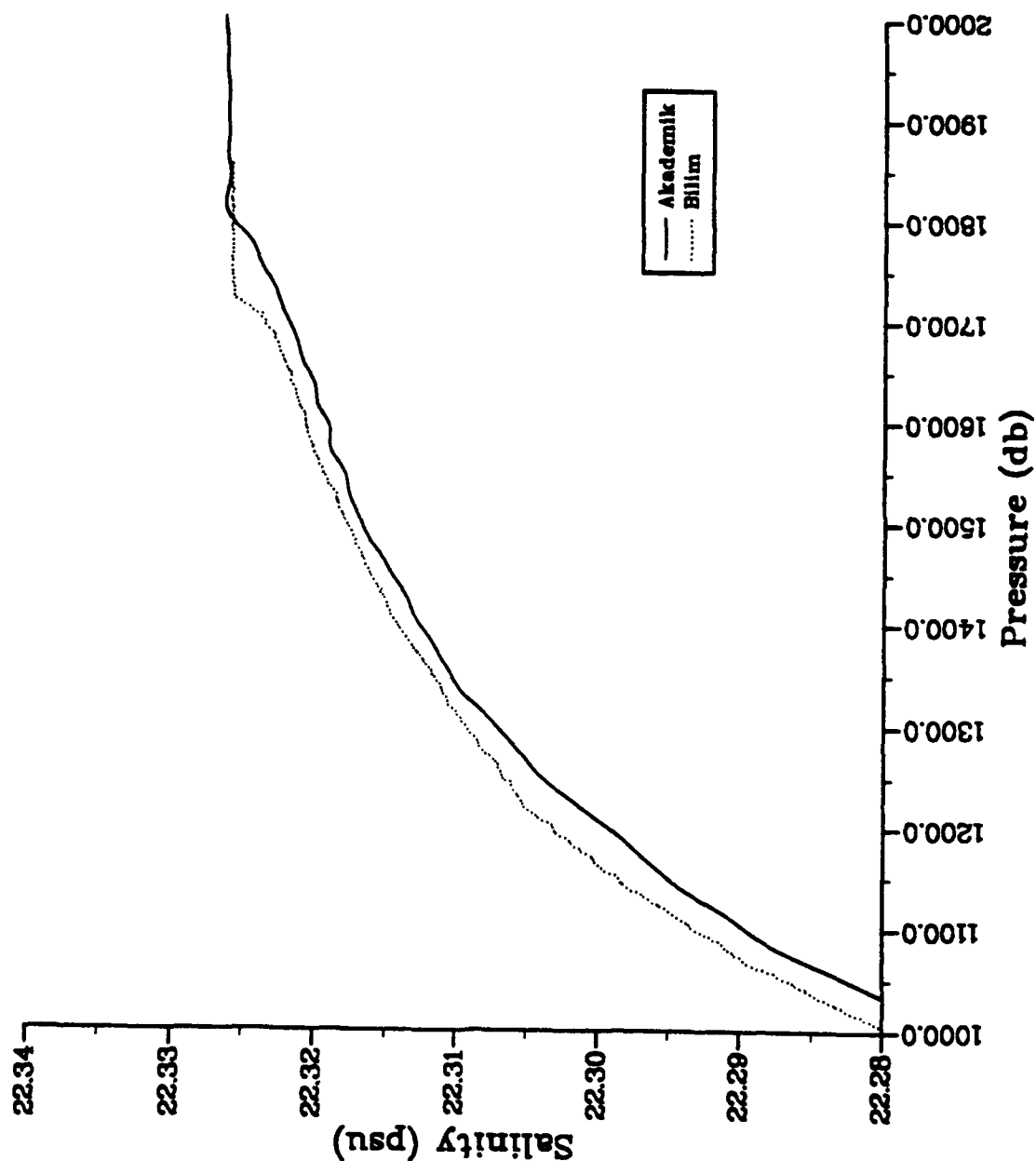


Figure 27: After intercalibration, the salinity data for the Akademik and the Bilim are approximately overlying at station M50M45. The low-frequency wiggles in the Akademik data are due to spiking in temperature and the effects of the low-pass filter. The salinities are within 0.003 psu or less throughout this depth range, and within 0.01 psu within the bottom mixed layer.

## M50M15 Final Intercomparison

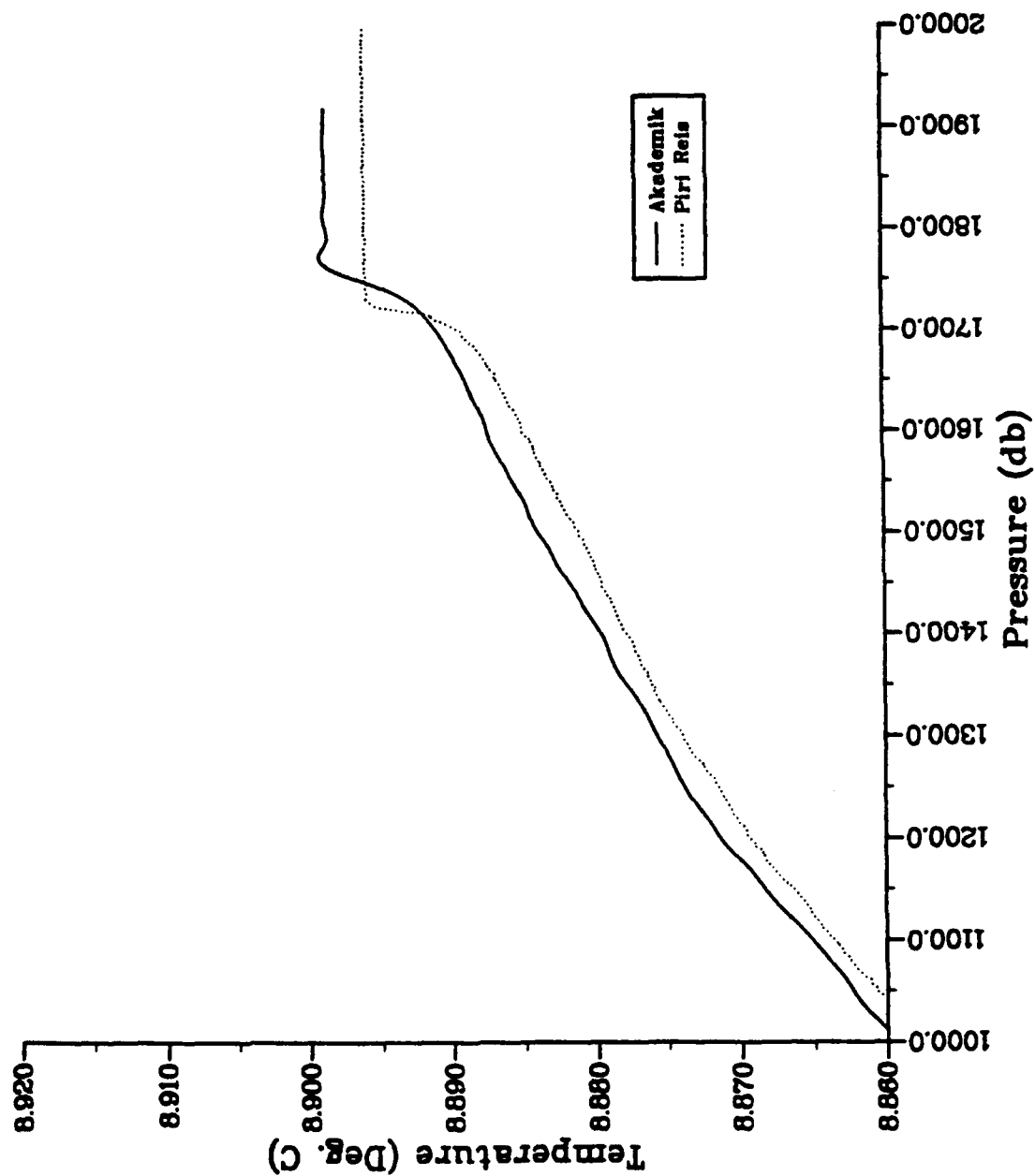


Figure 28: After intercalibration, the temperature data for the Akademik and the Piri Reis are approximately overlying at station M50M15. The temperatures are within 0.005°C or less throughout this depth range, and the temperatures in the bottom mixed layer are less than 0.003°C different.

## M50M15 Final Intercomparison

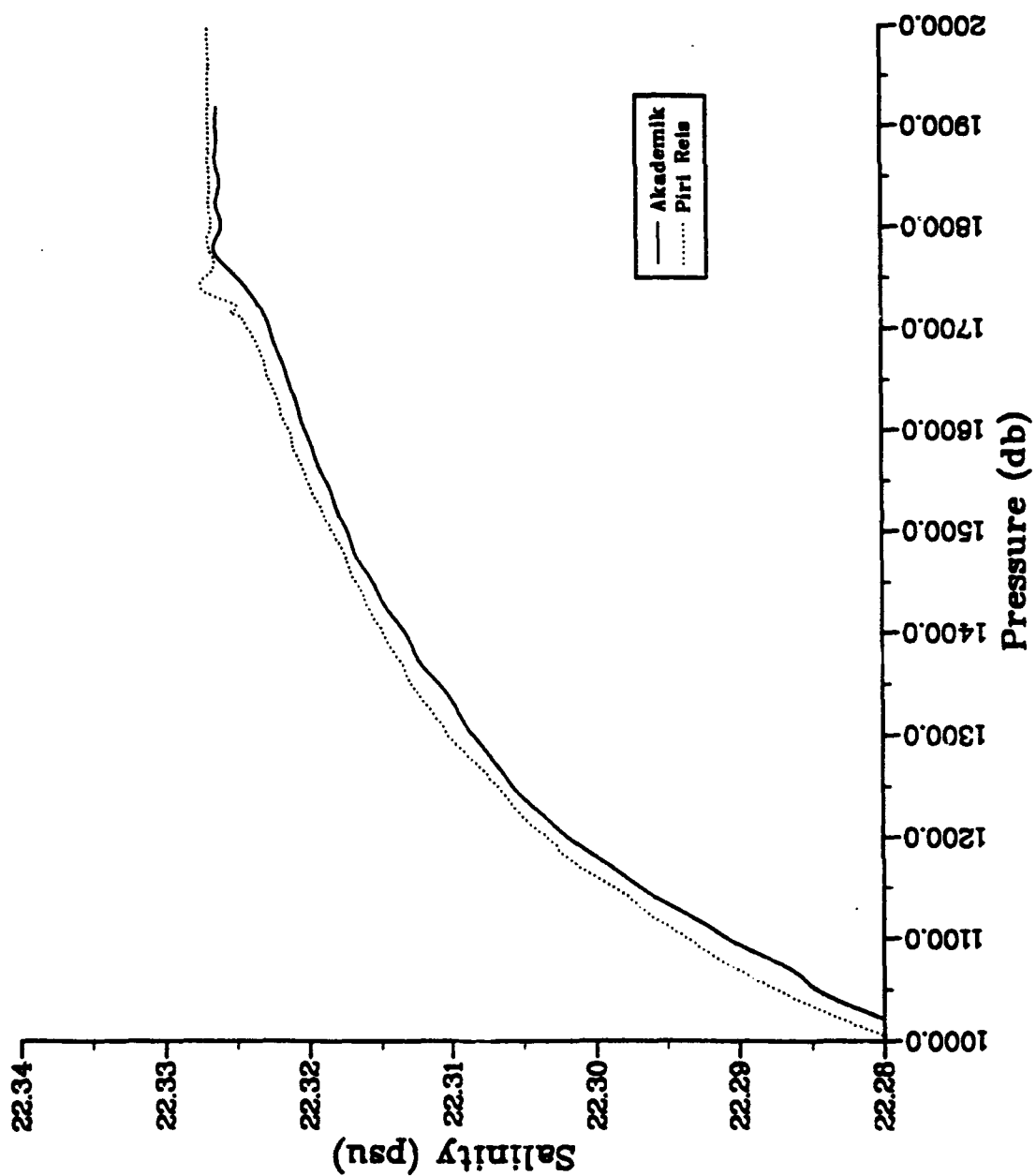


Figure 29: After intercalibration, the salinity data for the Akademik and the Piri Reis are approximately overlying at station M50M15. The salinities are within 0.003 psu or less throughout this depth range, and within 0.01 psu within the bottom mixed layer.

## M10X45 Final Intercomparison

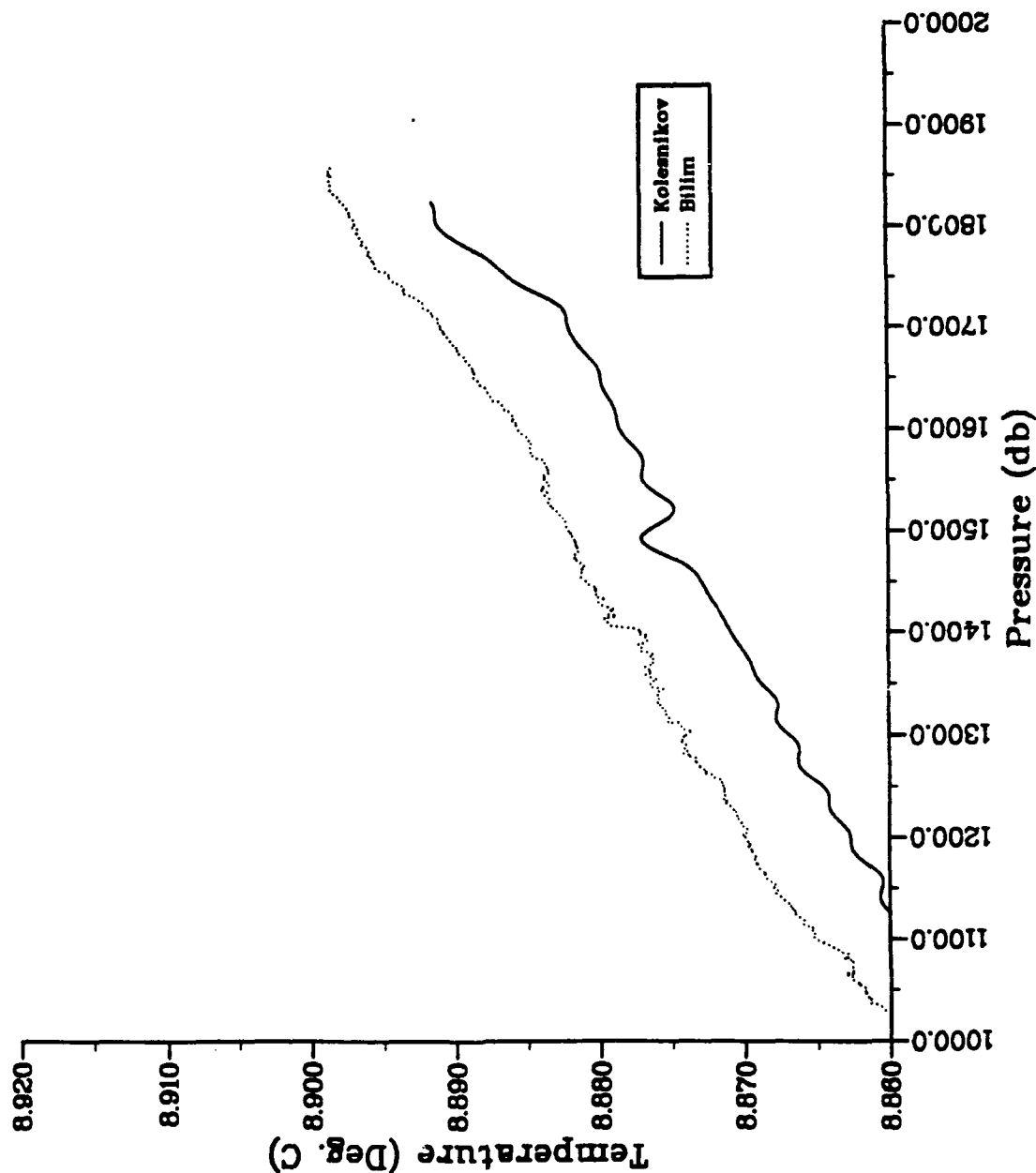


Figure 30: After intercalibration, the temperature data for the Kolesnikov and the Bilim are offset at station M10X45. The temperatures are within 0.01°C or less throughout this depth range. The temperature difference reflects the decision to apply one regional, average temperature correction to the Kolesnikov data, rather than a time-dependent value (see Fig. 7).

# M10X45 Final Intercomparison

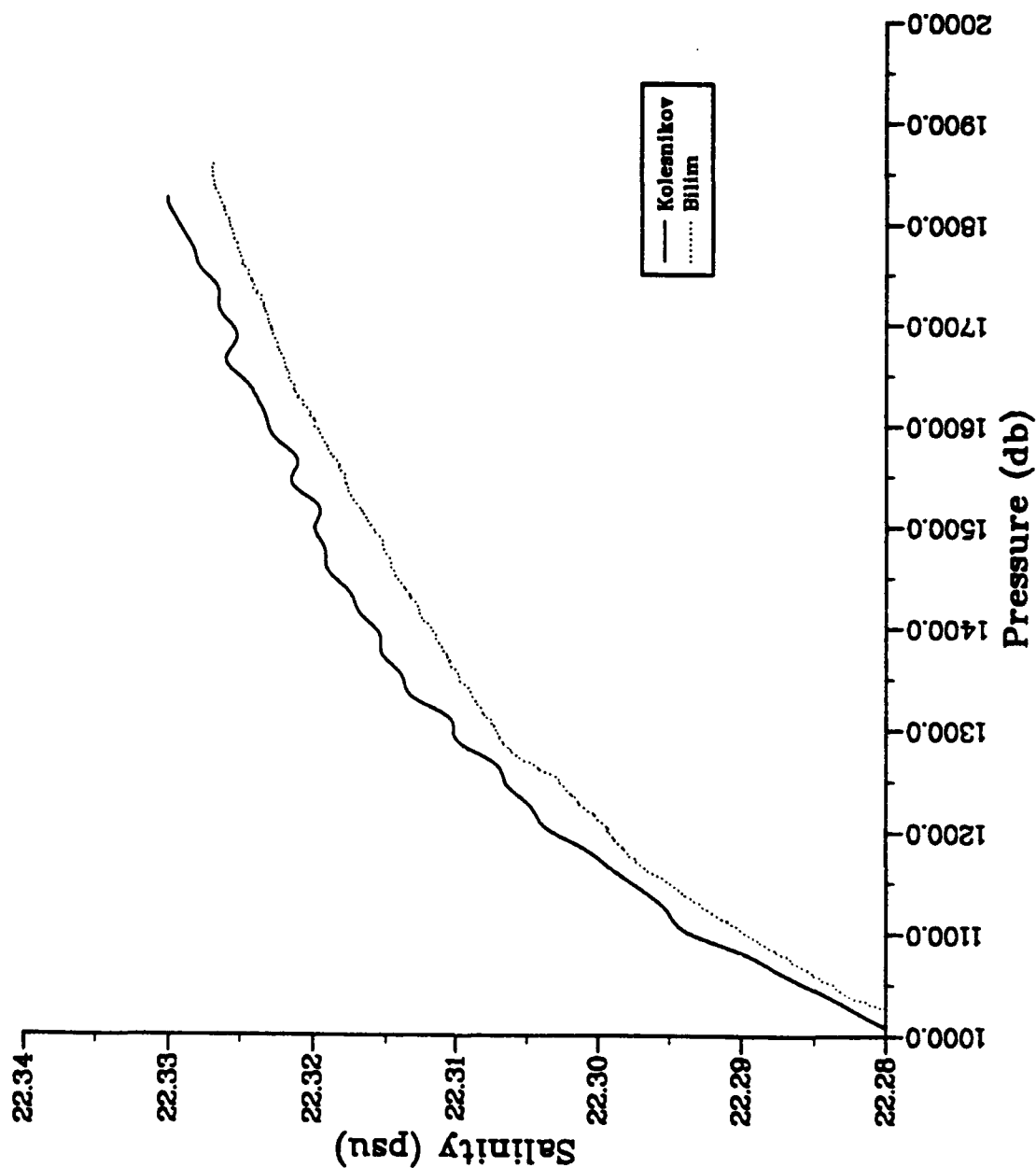


Figure 31: After intercalibration, the salinity data for the Kolesnikov and the Bilim are offset at station M10X45. The salinities are within 0.005 psu or less throughout this depth range. The differences reflect in part the temperature difference, and the depth-dependent conductivity correction.

# N10Q45 Final Intercomparison

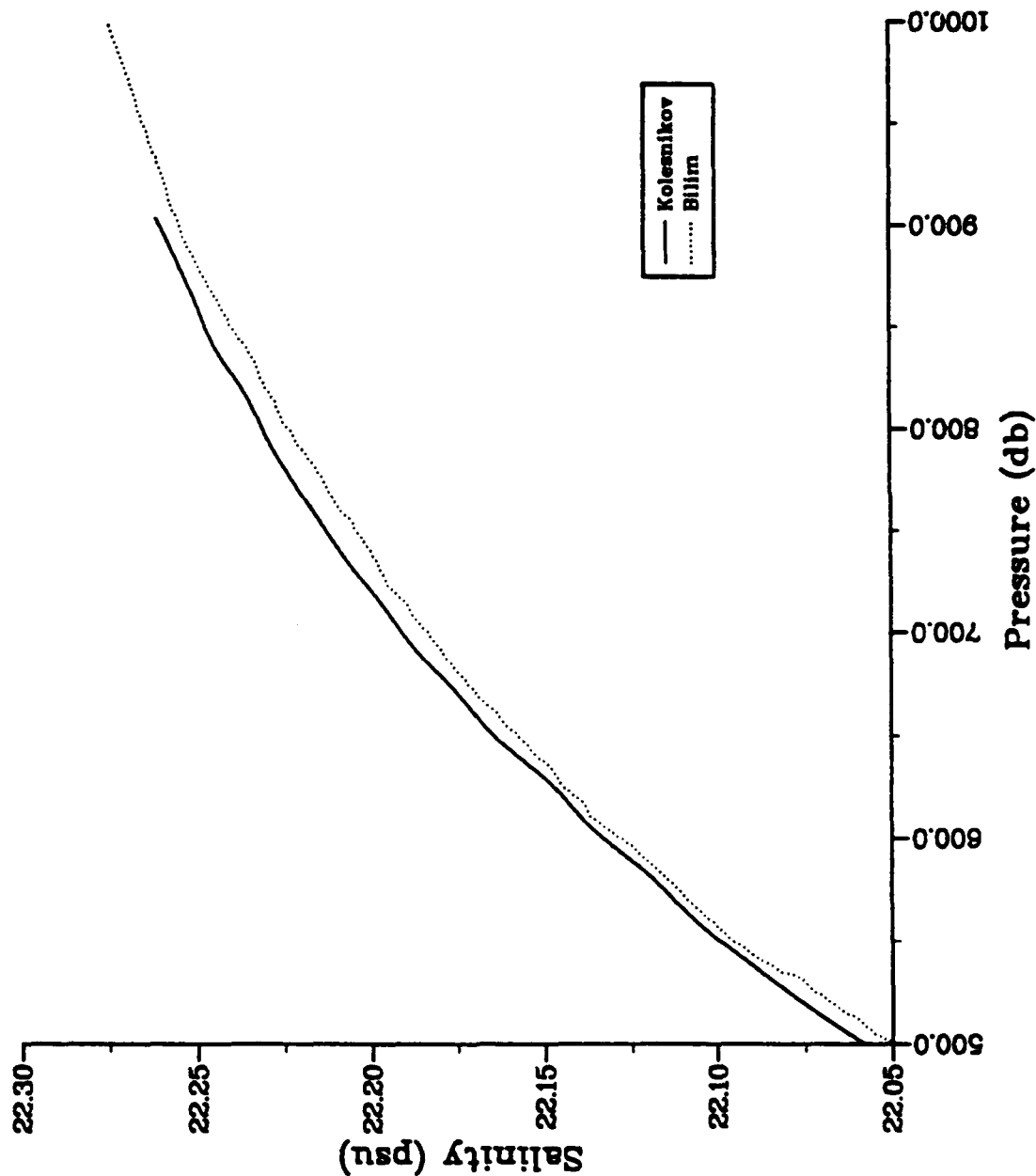


Figure 32: After intercalibration, the salinity data for the Kolesnikov and the Bilim are nearly overlapping at station N10Q45. The salinities are within 0.003 psu or less over this depth range. Contrast this excellent fit with Fig. 31 at another station.



# N10Q45 Final Intercomparison

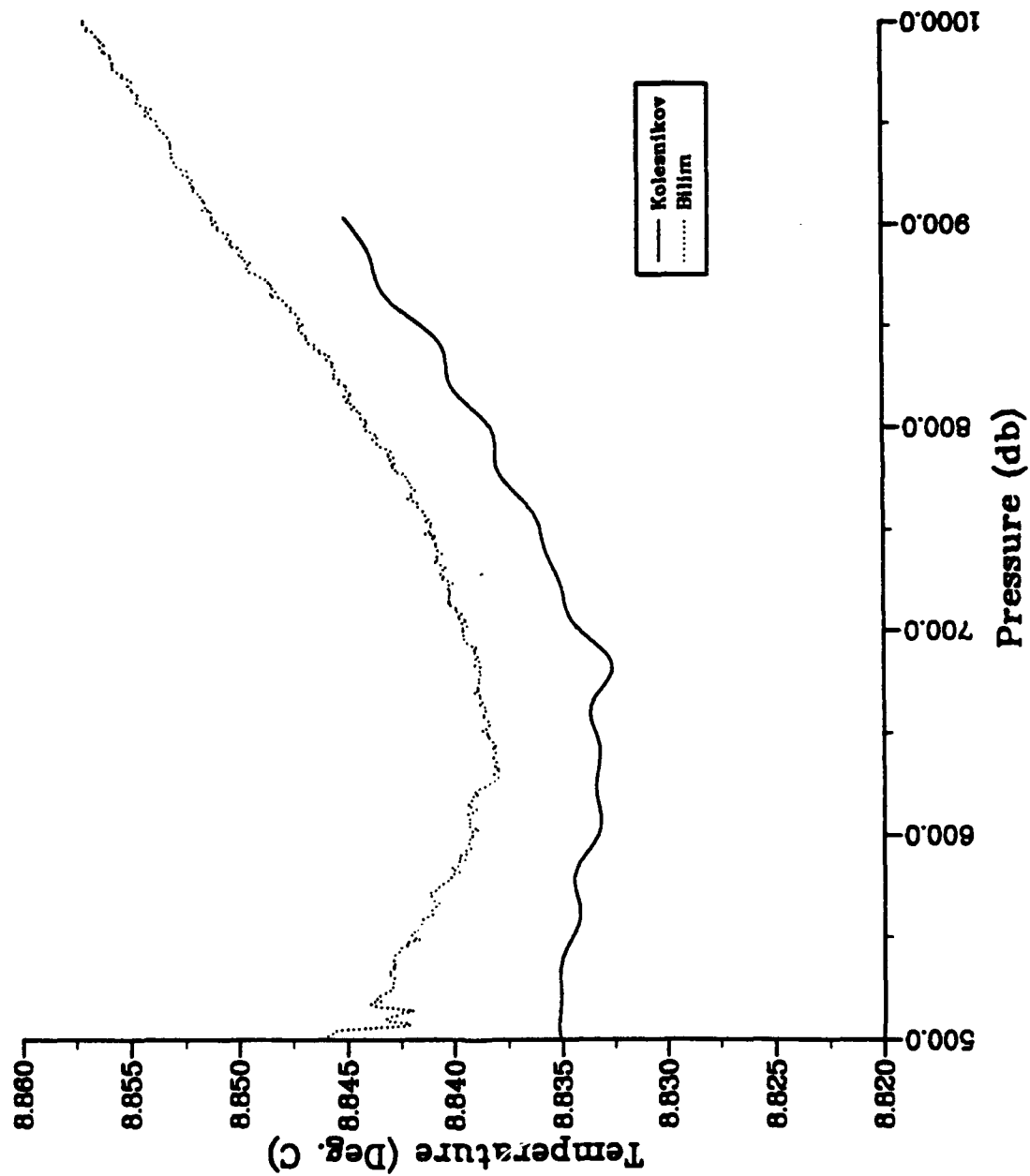


Figure 33: After intercalibration, the temperature data for the Kolesnikov and the Bilim are offset at station N10Q45. The temperatures are within 0.01°C or less over this depth range.

# N30N45 Final Intercomparison

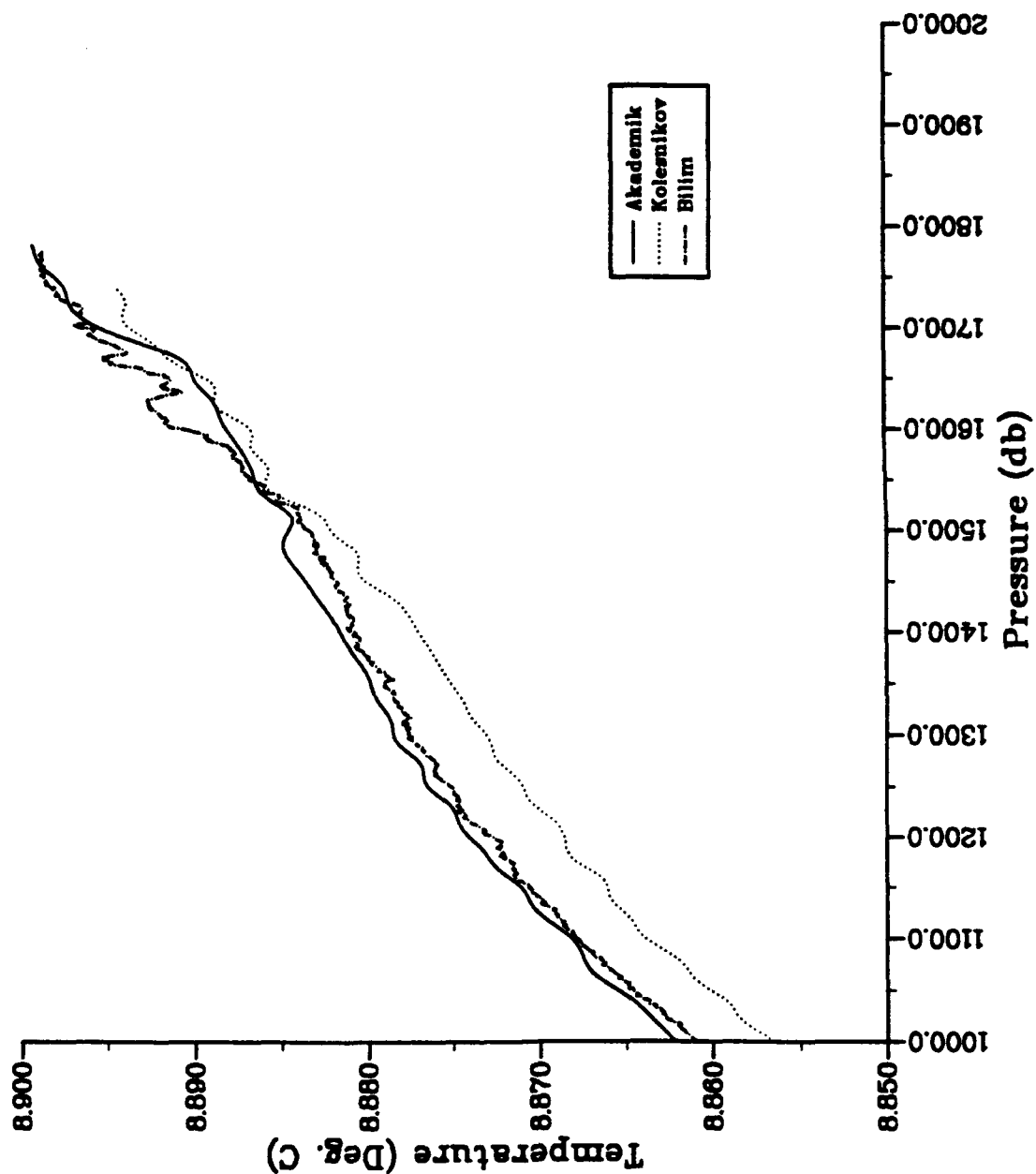


Figure 34: After intercalibration, a temperature comparison between the Akademik, Kolesnikov, and Bilim. at station N30N45. The temperatures are within 0.005 except for the Kolesnikov in the shallower portion of the section.

## N30N45 Final Intercomparison

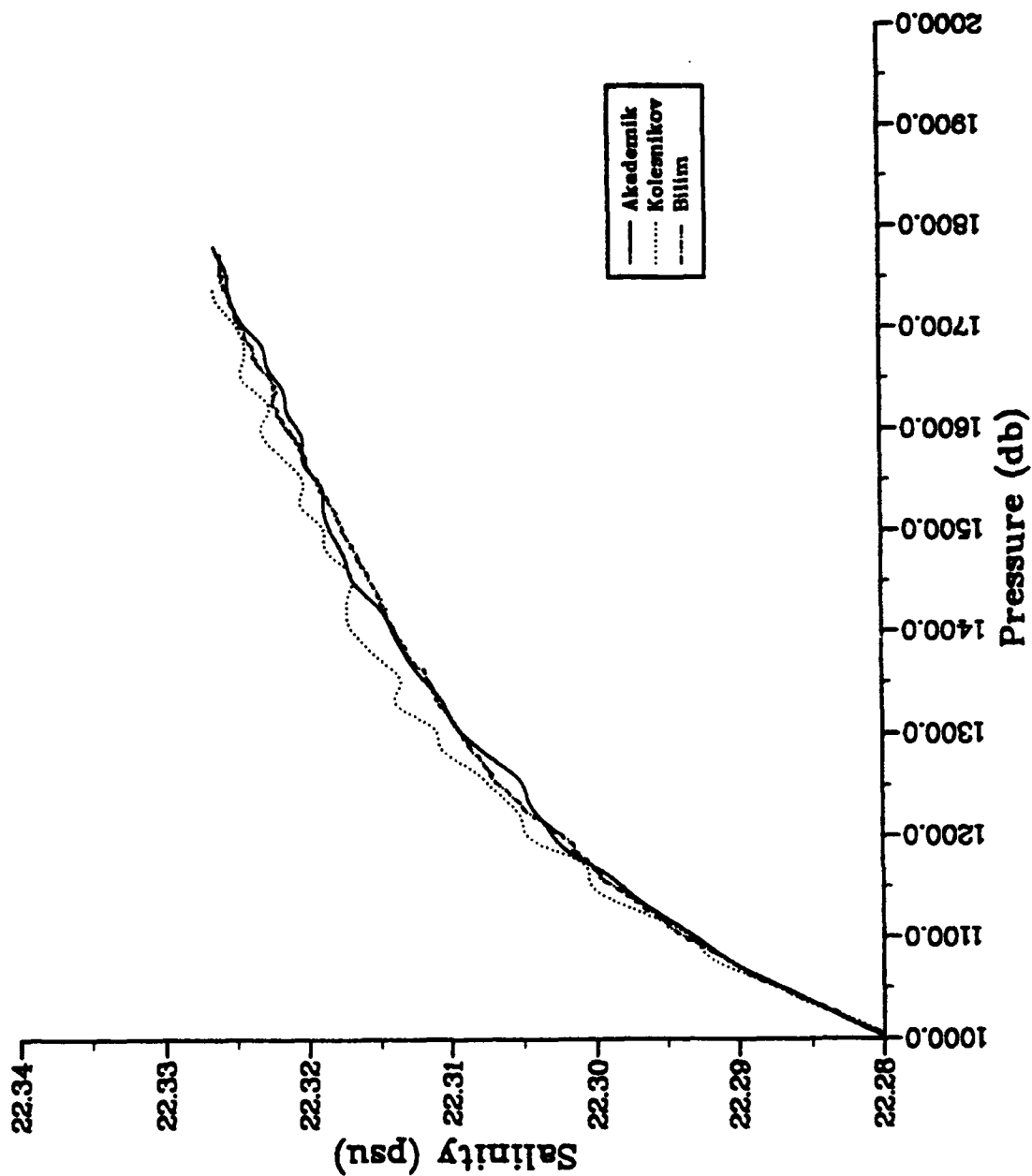


Figure 35: After intercalibration, a salinity comparison between the Akademik, Kolesnikov, and Bilim at station N30N45. The salinities are all within 0.005 psu. The wiggles in the Kolesnikov salinity reflect discontinuities in the temperature data for the CTD.

**TABLE 4**  
**TEMPERATURE DIFFERENCES (1200-1400 db)**  
**(°C)**

Station Code (Table 3)	Akd.-P. Reis	Akd.-Bilim	Bilim-P.Reis	Bilim-Kolesnikov before after Filtering	Akd.-Kolesnikov before after Filtering
226				-0.023±0.001	-0.023±0.0008
266				-0.003±0.001	-0.003±0.0007
50	-0.002±0.004				
70	-0.002±0.006	-0.001±0.0006	+0.003±0.0003*		
82		0.008±0.0006			
83					-0.005±0.0015
101		0.001±0.0004		-0.006±0.001	-0.005±0.0010
165(B)/173(K)				-0.021±0.001	-0.021±0.0007
203(B)/215(K)				-0.009±0.001	-0.009±0.0006
24(R)/42(B)			-0.002±0.001		
247(K)/248(B)				-0.020±0.0006	
147(K)/148(B)				-0.012±0.0006	

\* Station 50 is used for P. Reis

**TABLE 5**  
**CONDUCTIVITY DIFFERENCES (1200-1400 db)**  
**(S/M)**

Station Code (Table 3)	Akd.-P. Reis	Akd.-Bilim	Bilim-P. Reis	Bilim-Kolesnikov before Filtering	Akd.-Kolesnikov before Filtering
226	-0.005±0.001 -0.006±0.001	0.003±0.001 0.008±0.001	-0.009±0.0004	-0.014±0.002	-0.003±0.001
266				-0.025±0.0006	
50				-0.011±0.001	
70				-0.022±0.0009	
82					
83	0.007±0.0008	0.007±0.0008	-0.013±0.0003	-0.011±0.001	-0.013±0.001
101				-0.021±0.0008	
165(B)/173(K)				-0.012±0.001	
203(B)/215(K)				-0.023±0.0010	
24(R)/42(B)				-0.012±0.001	
247(K)/248(B)	0.006±0.001	0.006±0.001	-0.010±0.0003	-0.021±0.0006	-0.004±0.001
147(K)/148(B)				-0.025±0.0010	
				-0.022±0.0007	-0.015±0.001

TABLE 6

WATER BOTTLE SAMPLE RESULTS: IN SITU AND TITRATED

	STATION	PRESSURE	CTD cond	titr. cond	titration(ckp)	ctd-titr. cond
1	M50V45	1046.000	25.01200	25.00300	24.9991	-0.0129
2	M50W45	1042.000	25.00900	25.00410	25.0002	-0.0088
3	M30X15	1006.000	24.98800	24.98050	24.9767	-0.0113
4	M30X45	756.000	24.80400	24.78980	24.7870	-0.0170
5	M10Y15	767.000	24.80400	24.79170	24.7888	-0.0152
6	M10Y45	509.000	24.53300	24.50960	24.5077	-0.0253
7	L50Z15	1110.000	25.04500	25.04200	25.0378	-0.0072
8	M30Z15	513.000	24.53300	24.52150	24.5196	-0.0134
9	M40Z00	759.000	24.80700	24.79750	24.7947	-0.0123
10	M30Y45	403.000	24.37400	24.36320	24.3617	-0.0123
11	M30Y15	1524.000	24.68900	25.22640	25.2206	0.0000
12	M50Y45	760.000	24.81800	24.81220	24.8094	-0.0086
13	M50X45	1008.000	24.98500	25.00650	25.0027	0.0177
14	M50X15	1018.000	24.99900	24.97880	24.9750	-0.0240
15	N10X15	808.000	24.85100	24.83720	24.8342	-0.0168
16	N24X35	1165.000	25.07300	25.06280	25.0584	-0.0146
17	N30W45	1019.000	24.99300	24.98400	24.9802	-0.0128
18	N50W45	762.000	24.80900	24.80530	24.8025	-0.0065
19	P10W15	762.000	24.80700	24.78020	24.7774	-0.0296
20	P10W15	1013.000	24.99600	24.98950	24.9857	-0.0103
21	P10W15	1731.000	25.31890	25.31250	25.3059	-0.0130
22	N50W15	810.000	24.85600	24.84280	24.8398	-0.0162
23	N30W15	508.000	24.56300	24.59230	24.5904	0.0274
24	N10W45	762.000	24.81800	24.81470	24.8119	-0.0061
25	N10W15	906.000	24.93300	24.92620	24.9228	-0.0102
26	N30V45	1520.000	25.23200	25.22650	25.2207	-0.0113
27	N10V15	2027.000	25.43400	24.98880	24.9812	0.0000
28	N10V45	1032.000	25.00100	25.42460	25.4207	0.0000
29	N30V15	408.000	24.41200	24.39860	24.3971	-0.0149
30	N30V15	1015.000	24.98800	24.96850	24.9647	-0.0233
31	N50V45	605.000	24.67500	24.66860	24.6664	-0.0086
32	N50V15	504.000	24.56800	24.57620	24.5743	0.0063
33	N50T45	759.000	24.82300	24.81850	24.8157	-0.0073
34	N30T45	490.000	24.40600	24.43360	24.4318	0.0258
35	N30T15	1212.000	25.09200	25.08080	25.0762	-0.0158
36	N50T15	1015.000	24.99000	24.97710	24.9733	-0.0167
37	P10T45	1519.000	25.23200	25.20490	25.1992	-0.0328
38	P10V15	1019.000	24.99900	24.99460	24.9908	-0.0082
39	P10V45	1831.000	25.36000	25.35430	25.3473	-0.0127
40	P28V45	749.000	24.80700	24.79700	24.7942	-0.0128
41	P30V15	507.000	24.53800	24.52910	24.5272	-0.0108
42	P45V05	608.000	24.68100	24.67860	24.6763	-0.0047
43	P30T45	913.000	24.93500	24.92110	24.9177	-0.0173
44	P10T15	808.000	24.84800	24.83950	24.8365	-0.0115
45	P30T15	711.000	24.77100	24.55140	24.5488	0.0000
46	P30S45	1022.000	24.98800	24.96240	24.9586	-0.0294
47	P10S45	1822.000	25.35500	25.34900	25.3421	-0.0129
48	N50S45	505.000	24.52200	24.51830	24.5164	-0.0056
49	N30S45	1052.000	25.00400	24.99450	24.9906	-0.0134
50	N30S15	1416.000	25.18200	25.14980	25.1445	-0.0375
51	N50S15	810.000	24.83700	24.82700	24.8240	-0.0130
52	P10S15	909.000	24.91100	24.90110	24.8977	-0.0133
53	P39S15	505.000	24.54900	24.54110	24.5392	-0.0098
54	P36R45	757.000	24.81500	24.80700	24.8042	-0.0108
55	P10R45	2029.000	25.43400	25.43060	25.4229	-0.0111
56	P10R15	1050.000	25.01200	25.00810	25.0042	-0.0078

	STATION	PRESSURE	CTD cond	titr. cond	titration(ckp)	ctd-titr. cond
57	N50R15	1515.000	25.23200	25.23120	25.2255	-0.0065
58	N50R45	813.000	24.85600	24.85310	24.8501	-0.0059
59	N30R45	1011.000	25.99000	24.98680	24.9830	0.0000
60	N10R15	1015.000	24.99000	24.98570	24.9819	-0.0081
61	N10R15	1523.000	25.22900	25.22350	25.2177	-0.0113
62	N10R15	2044.000	25.43700	25.42180	25.4140	-0.0230
63	N10Q45	906.000	24.92500	24.91600	24.9126	-0.0124
64	N30R15	1029.000	25.00400	24.99230	24.9884	-0.0156
65	N30Q45	1315.000	25.14400	25.13070	25.1257	-0.0183
66	N30Q45	1723.000	25.31900	25.31600	25.3095	-0.0095
67	N50Q15	1416.000	25.18500	25.18270	25.1774	-0.0076
68	N50Q15	1877.000	25.37400	25.36560	25.3585	-0.0155
69	P10Q15	1039.000	24.99600	24.98520	24.9813	-0.0147
70	P25Q08	406.000	24.37900	24.38290	24.3814	0.0024
71	P07Q45	883.000	24.91400	24.90080	24.8975	-0.0165
72	N30Q15	507.000	24.56300	24.56050	24.5586	-0.0044
73	N30P45	1516.000	25.23200	25.22640	25.2207	-0.0113
74	N30P45	1925.000	25.39300	25.39050	25.3832	-0.0098
75	N50P45	1040.000	25.00100	24.99090	24.9870	-0.0140
76	N50P15	1211.000	25.09400	25.09380	25.0892	-0.0048
77	N30P15	911.000	24.92700	24.92550	24.9221	-0.0049
78	N30N45	1619.000	25.27500	25.26640	25.2603	-0.0147
79	N50N45	1040.000	25.00400	24.99930	24.9954	-0.0086
80	N30N15	1425.000	25.19600	25.19310	25.1877	-0.0083

## **INTERCALIBRATED DATA ANALYSIS**

Using available intercalibrated data, various calculations were made to illustrate different aspects of the physical oceanography of the Black Sea. These calculations were compared to subjective analyses of hydrophysical fields to assure the validity of the computer analysis. Computer analysis was completed on a SUN SparcStation II, using MATLAB and UNIMAP software licensed to the Woods Hole Oceanographic Institution.

**DYNAMIC HEIGHT:** Calculations of dynamic height were made using standard analysis techniques. All calculations were referenced to the 900 db level. Below this level, prior calculations have shown dynamic height contributions to be on the order of mm's. Neglect of lower levels does not affect the interpretation of these calculations. The dynamic topography at 5 db (Figure 36) depicts the major circulation within the Black Sea, including the rim current, the major sub-basin scale cyclones, plus a series of anticyclones, some permanent, rimming the basin. Additional dynamic topography plots are included in Appendix V.

**HORIZONTAL AND VERTICAL SECTIONS:** Horizontal and vertical sections of temperature, salinity, and density were made along several transects across the Black Sea to describe briefly the distribution of these properties. Results are provided in Appendix V.

## **RECOMMENDATIONS FOR FUTURE**

### **SEVASTOPOL WORKSHOP: FEBRUARY 1992**

An interdisciplinary workshop will be held in Crimea, Ukraine, in February 1992. The workshop will be held to perform the complete intercalibration of biological and chemical data, and to integrate those data with the physics. We recommend that the following take place:

- Adoption of the simpler numerical scheme identifying stations instead of the more cumbersome scheme adopted during the cruise.
- That technical reports be issued on the intercalibration of the biological and chemical data.
- That the full data sets be placed on a common computer, and analyzed jointly to examine for inter-relationships in an interdisciplinary sense.

### **PUBLICATIONS**

Joint publications for the HYDROBLACK '91 material will follow the general guidance of the Cruise Planning Document (see Appendix II). In general, we expect the publications to be in International as well as National journals, and will follow in several general areas:

- Basin-wide CTD results
- Coastal ocean physics and site-specific hydrography
- Interdisciplinary relationships between the different data sets: such as oxygen distribution, hydrogen sulfide distribution, suboxic zones, etc. and their relationship to the physics and biology.

The publications should be sent to the Steering Committee office, to be given a publication number for the Cooperative Marine Science Program on the Black Sea, and to be listed in summaries of Cooperative Program results. Authorship is expected to include participants from the member countries. We recommend that specific articles be outlined during the Crimea meeting in February, 1992.





## **FUTURE HYDROBLACK EXPEDITIONS**

The Hydroblack framework is an extremely useful one for basin-wide monitoring and observations. We recommend that these cruises continue on a twice-yearly basis, to provide complete seasonal data on the ocean physics, biology, geology, and chemistry. These quasi-synoptic measurements will be useful not only for basin-wide monitoring, but also for providing the framework for site-specific, process-oriented studies that will take place as part of the Cooperative Marine Science Program.

Future Hydroblack expeditions should be carried out with more complete intercalibration plans, particularly for the biological and chemical measurements. Future Hydroblack expeditions should learn from the deficiencies of HYDROBLACK '91. One goal of the February 1992 Crimea meeting should be to clarify improvements to the sampling and analysis protocol for the Hydroblack expeditions of the future.

For example, the present CTD intercalibration exercise demonstrated several deficiencies in the CTD analysis:

- The CTD's used should have accuracies on the order of that provided by the Sea Bird SBE 9. Since deep-water processes are of interest to the interdisciplinary study team, the CTD's must be accurate to full water depths of 2200 m.
- More effort should be placed on having ships take synoptic intercalibration samples in the Black Sea during the cruise. Variability in upper waters during intervals of weeks complicates the intercalibration exercise.
- Vertical bottle samples should be taken at several intercalibration stations, including bottles taken at approximately 5 depths throughout the water column. This exercise will help calibrate the individual CTD's throughout the cruise, to evaluate for drift and calibration offsets. The bottles used must be glass, and must follow a specific protocol to assure good salinities can be derived from high quality salinometers.
- Sampling density (rate, lowering speed, etc.) must be carefully adhered to, to prevent spiking near the intense chemocline. Similarly, water column sampling for chemistry and biology should be aware of the filtering effects of a heaving ship with a sampler hanging in a sharp chemocline.

Similar improvements should be derived for the other biological and chemical sampling and analysis protocols, and implemented during future Hydroblack expeditions.

Finally, additional measurements should be incorporated into future Hydroblack expeditions. For instance:

- Current meters would be useful for linkage with the dynamic height calculations, particularly for use with diagnostic numerical circulation models.
- Tracer studies, focusing on cesium and other Chernobyl products, should be incorporated to improve our understanding of mixing processes on longer time scales.
- Numerical model simulations should be incorporated to provide a feedback between model development and field data.

## REFERENCES

- Fofonoff, N.P. and R.C. Millard, 1983. Algorithms for Computation of Fundamental Properties of Seawater. Unesco Technical Papers in Marine Science NO. 44, 53 pp.
- Oppenheim, A.V. and R.W. Schaffer, 1975. Digital Signal Processing. Prentice-Hall, Englewood Cliffs, New Jersey, 585 pp.

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P. Barrows and F. Gable helped make the arrangements for this intercalibration meeting at Woods Hole. Funding for this meeting was provided by the Vettleson Foundation and the Mobil Foundation Inc., through the Coastal Research Center of the WHOI. Funding for HYDROBLACK 1991 itself came from the individual countries, the Andrew W. Mellon Foundation (New York), the Regional Environmental Center for Central and Eastern Europe (Budapest), and the National Science Foundation of the U.S.A.

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**APPENDIX I:**  
**WORKSHOP AGENDA**

**HYDROBLACK 1991**  
**INTERCALIBRATION MEETING**  
**1-10 DECEMBER 1991**

**SCHEDULE**

**30 Nov - 1 Dec.:      Arrival of participants to Woods Hole**

**Monday, 2 Dec. 0800 Arrival in Clark 257**

**Agenda:** Discuss goals of intercalibration exercise.  
          Agree on strategies for intercalibration exercise  
          Show preliminary results of some intercalibration procedures  
          Discuss programming languages, plotting packages, etc.  
          View intercalibration issues on computer screen: evaluate techniques for  
              filtering, wild-point editors, etc.  
          Discuss bottle samples versus ship intercalibration procedures  
          Enter Parshin data to SUN workstation  
**Evening:** Free. Shopping as required.

**Tuesday, 3 Dec. 0800 Arrival in Clark 257**

**Agenda:** Complete programming for filtering, spike-removal, and determine  
          intercalibration constants.  
          Apply intercalibration to all stations

**1800:** Dinner at Aubrey's

**Wednesday, 4 Dec. 0800: Arrival in Clark 257**

**Agenda:** Complete intercalibration for all stations.  
          Prepare horizontal and vertical sections of hydrographic parameters, to  
              evaluate the success of the intercalibration. Examine and correct for  
              poor intercalibration  
          Add available chemical and biological data to data base. Examine the  
              interrelationships between these data.

**Evening:** Free. Shopping in Town, touring, etc.

Thursday, 5 Dec. 0800: Arrival at Clark 257

Agenda: Calculate dynamic heights for all intercalibrated stations. Reference to 1000 m depth.

Plot hydrophysical fields, including T-S diagrams, sections, etc. Discuss deep sea and shelf circulation patterns, water masses.

Begin final plots and writing for technical report: Intercalibration study.

Evening: free.

Friday, 6 December 0800: Arrival at Clark 257

Agenda: Complete technical report draft.

Evening: Cocktail party at Aubrey's.

Saturday, 7 December 0800: Arrival at Clark 257 (Pick-up: no shuttle service)

Agenda: Outline paper(s) on HYDROBLACK 1991: discuss science issues. For example, discuss articles on water masses, general circulation, relationships to oxygen/chemoclines, shelf mixing processes, etc.

Evening: Free

Sunday, 8 December Possible tour of Cape Cod or trip to Boston.

Monday, 9 December 0800: Arrival at Clark 257

Agenda: Discuss science issues.

Evening: Free

Tuesday, 10 December 0800: Arrival at Clark 257

Agenda: Review Technical Report on Intercalibration exercise. Finalize report.

Wednesday, 11 December Depart Woods Hole

**APPENDIX II:**

**HYDROBLACK 91 CRUISE PLAN**



APPENDIX II

HYDROBLACK-1991

INTERNATIONAL RESEARCH CRUISE

ON HYDROGRAPHY OF THE BLACK SEA

CRUISE PLANNING

JULY 1991

## 1. SCIENTIFIC OBJECTIVES OF HYDROBLACK-1991

The existing scientific studies on the Black Sea oceanography indicate that the major physical, chemical and biological processes are poorly understood and further studies are essential. There is growing recent evidence that the environmental conditions of the sea are changing. It is timely to carry out multi-institutional interdisciplinary studies on the oceanography of the Black Sea because the problems to be addressed have regional importance, their solutions are of practical consequence, and they require coordinated research efforts between neighboring countries.

Dynamical characteristics of the Black Sea are influenced by winds and density differences due to heating/cooling, evaporation, precipitation, inflow/outflow from straits and the river run-off. All these sources act on the Black Sea and contribute to its temporally and spatially complex pattern of circulation. The circulation consists of a permanent cyclonic rim current complicated by a field of eddies, intense jets, filaments and meandering currents along the coasts. The circulation seems to have both transient and stationary components: at times the mesoscale variability appears to mask the general circulation.

In the Black Sea, the so-called Cold Intermediate Water mass is formed in the northwestern shelf region as well as in the upwelled waters of the basin's interior. Neither the process of formation (e.g. intensity and patchiness of convection events) nor the subsequent spreading, mixing and transformation characteristics of this water mass are clearly understood and deserve further scientific studies.

The overall scientific objective for the Black Sea oceanographic studies is to establish a definitive phenomenology to understand and quantify the roles of the fundamental physical processes and their impact on the biology and chemistry of the Black Sea. The results will form a better understanding of the transport and dispersion of material, the biological productivity of the basin, the efficient utilization of marine resources and environmental management including the control of pollution. The following are some specific problems that need to be addressed to achieve this objective:

- \* intercomparison of the main forcing mechanisms; the wind versus thermohaline forcing, source/sink flow through

straits as reflected in the spatial as well as seasonal and interannual variability and budgets,

- \* the role played by the topography and the irregular coastline,

- \* characteristics of the convection processes associated with the Cold Intermediate Water formation and its subsequent sinking, spreading and mixing,

- \* identification of the major features of circulation, its variability, energetics and basic space and time scales,

- \* analysis of available historical data sets and satellite imagery (both AVHRR and CZCS),

- \* determination of the dissolved oxygen and hydrogen sulfide concentrations and the features of the oxic/anoxic interface,

- \* the influence and implications of the circulation on the distribution of biological and chemical properties,

- \* determination of important sources and sinks of nutrients and the role of eddies in the nutrient transport and primary productivity,

- \* determination of horizontal and vertical material fluxes within the sea and their variability

- \* investigation of the primary biogeochemical processes of the euphotic and aphotic zones of the water column,

- \* impact of eddies and other features of circulations on fisheries through recruitment and/or production,

The program will contain not only hydrographic and biochemical measurements, but also remotely sensed data to aid in the interpretation of the hydrophysical measurements as well as numerical modelling studies to motivate a better understanding of the dynamical background of the physical processes.

## 2. ELEMENTS OF THE HYDROBLACK-1991 RESEARCH PROGRAM

In order to achieve some of the scientific objectives specified in the previous section, a basin-wide multi-institutional survey is planned during September 1991. The survey is aimed to quantify the spatial distribution of important physical and biochemical parameters and their interrelations with the mesoscale features (eddies, jets and filaments, etc.). The objectives listed above can be accomplished by the determination and/or measurement of the following parameters:

### Meteorological Measurements

The following meteorological parameters will be measured aboard each ship:

1. Time (GMT; Greenwich Mean Time)
2. Location (latitude/longitude, using GPS if possible)
3. Air temperature (degrees Celsius)
4. Humidity (Relative humidity, dew point or wet bulb)
5. Wind speed and direction (m/sec, degrees from north)
6. Atmospheric pressure (millibars)
7. Sea surface temperature (degrees Celsius)

These measurements will be made every three hours starting from 00.00 GMT. Parameters 3 through 5 should be measured as closely as possible to the 10m height as required by bulk flux formulae. Additional measurements could be helpful but are not required.

### Physical Measurements

The station network for the HydroBlack-1991 September survey is shown in Figure 1a,b. The CTD stations (Figure 1a) are located on a grid with spacing of  $1/3^\circ$  latitude (20 miles) and  $1/2^\circ$  longitude (about 22 miles). CTD measurements (depth versus temperature and conductivity) will be obtained up to a nominal depth of 1000m excluding the predetermined intercalibration stations and one out of every third deep station, where the measurements will extend to the bottom (about 2000m). CTD system should be lowered at a rate of about 0.5 m/sec and data should be collected during downcast.

The raw CTD data obtained for all stations shall be

processed by each party in the form of pressure, temperature, salinity, sigma-t. The processed data must be in bin-averaged form at 1 db pressure intervals.

### **Biochemical measurements**

The biochemical parameters (Table 1) will be measured at the stations shown in Figure 1b. Dissolved oxygen, hydrogen sulfide, phosphate, nitrate and chlorophyll-a are the main parameters to be measured in the HydroBlack-1991 program. The other parameters listed in Table 1 are optional.

Biochemical measurements are carried out at smaller number of stations along selected transects. These transects will be chosen before the cruise in the regions where important physical variability is anticipated. The water samples should be taken with the Rosette samplers at prespecified depth levels depending on the biological and chemical quantities desired. The standard depth levels specified for this study are 5m, 20m, 50m, 75m, 100m, 125m, 150m, 200m, 250m, 300m, 400m, 500m, 750m, 1000m, 1250m, 1500m, 1800m and 2000m.

Secchi disk depths will be measured at all of the CTD stations.

### **Intercalibration requirements**

Intercalibration constitutes an essential component of the HydroBlack-1991 program. All measurements should be carried out with calibrated instruments. Meteorological instruments should be calibrated with the local meteorological service before the cruise. CTD sensors should be calibrated before the cruise by the manufacturer.

Intercalibration stations are selected for the comparison and intercalibration of the different sets of instruments used in each joint research area. These stations should ideally be occupied simultaneously by the individual ships but a reasonable time lag between the measurements would have to be allowed. The uniform properties of the Benthic Boundary Layer (about 400m deep) near the bottom forms an ideal environment for the intercalibration of the physical measurements.

Integration of the CTD observations from different profilers requires an estimate of the error associated with each CTD profiler. Salinity values will be calibrated against salinometer in Woods Hole Oceanographic Institution (WHOI).

For this purpose, one 100 ml water sample will be taken during the upcast at a depth where temperature and salinity are vertically homogeneous. Salinity sample bottles will be provided by WHOI. The following information should be recorded at each station: Station name, Time & Date (GMT), CTD pressure, CTD temperature, CTD conductivity, CTD salinity (three decimal places), and the sample bottle number. After the cruise, the water samples and a copy of the station log will be sent to Dave Aubrey at WHOI where the bottle salinity will be measured with the high quality salinometer. The in situ true conductivity will then be calculated from the CTD pressure and temperature, and the bottle salinity. The difference between the in situ true conductivity and the CTD conductivity is the sensor error. Systematic errors can later be used to correct the raw conductivity.

For the intercalibration of nitrate, phosphate and chlorophyll-a, standard water samples will be provided by the Institute of Marine Sciences, Erdemli-Turkey. These samples will be distributed amongst parties prior to the cruise, if possible.

#### Remote Sensing

The HydroBlack-1991 program will also be supported by the remote sensing facilities of the participating institutions. Woods Hole Oceanographic Institution (USA), Marine Hydrophysical Institute - Ukrainian Academy of Sciences (USSR) and Institute of Marine Sciences - Middle East Technical University (TURKEY) will provide the AVHRR (infrared) imagery for the Black Sea. The imagery will include a sequence of pictures that will describe the temporal evolution of the features in the sea. A period of about one month starting from one week before the survey and ending a week after the end of the survey is accepted as the optimum period for the coverage of the AVHRR data.

The Institute of Marine Sciences - Middle East Technical University will attempt to provide the real time AVHRR infrared and visible satellite data through the Automatic Picture Transmission (APT) system in use at Erdemli campus (APT System gives three AVHRR pictures of the Black Sea per day with the 4km x 4km pixel resolution).

## Data Exchange

The processed CTD data sets (i.e. one meter bin-averaged and converted to the form of pressure, temperature, salinity and density) will be exchanged between all participating groups in the form of ASCII files on IBM compatible 5.25 or 3.50 inches flexible diskettes. The precise format of the CTD data is given in Table 2. The CTD data will be exchanged at Varna-BULGARIA during the Workshop on the Black Sea to be held at the end of September, 1991.

A workshop is planned in November 1991 to pool all the CTD data, make a collective data set and carry out the cooperative and synthetic scientific analysis. For this purpose, the quality control of the CTD data sets will be first checked for instrument error. They will then be intercalibrated with respect to bottle-calibrated CTD measurements and by other means which will be set during the workshop. The final form of the pooled data set will contain pressure, potential temperature, salinity and sigma-theta.

The place and time of the November 1991 workshop will be decided by the Steering Committee of the Black Sea programme during the Varna meeting.

Because a major part of the biochemical samples requires laboratory analyses, exchange of the biochemical data will be done within three months following the completion of the cruise. It is also exchanged in the form of ASCII files on the IBM compatible 5.25 and 3.50 inches diskettes. Considering the difficulty in assigning a common format for the data exchange of biochemical parameters, the form of the data will be decided individually by each party. A brief description of the format should, however, be provided together with the diskettes.

For a period of three years after exchange, the data will be considered to be property of the party collecting the data, and can not be published by another party without permission of the responsible party. Joint publications are encouraged. After three years, the complete data set will be considered common property of the participating institutions.

## Publications

On the basis of the data gathered during HydroBlack-1991 survey, a series of joint publications will be produced within the first three years. These joint publications will

bear the name of scientists actively participating in the HydroBlack-1991 program. They will be prepared in English and submitted to peer-reviewed oceanographic journals. Additional articles may also be prepared in the native languages of each party.

Exchange of scientists between the participating groups is desirable for previewing and evaluation of the data and the preparation of joint articles. The time and place of these meetings will be decided by the organizing committee of the HydroBlack-1991 program and is subject to the availability of funds.



### 3. DETAILED CRUISE PROGRAM

The station network presented in Figure 1a,b is covered by six ships. The name of the ships, cruise coordinators and the chief scientists assigned for each ship are given in Table 3. The equipment available on board for each ship are listed in Table 4. The cruise schedule for the ships is planned such that a quasi-synoptic results are achieved. The survey period will start within the first week of September, 1991 and is expected to continue not more than two weeks. Approximate dates of starting the survey for each ship are given in Table 5. The locations of stations which will be visited by each party are listed in Table 6.

Each ship will cover a certain region (Figures 2-4) but there are some overlapping stations which will be visited by more than one ship during the survey. These common stations are essential for intercalibration purposes.

Areas of responsibility assigned for each ship are shown in Figures 2-4. Figure 2a shows a total of 138 CTD stations to be visited by the Soviet ships. The R/V Vodyanitsky will cover 72 CTD stations situated within the northeastern part, the R/V Kolesnikov will cover 36 CTD stations in the central part of the Black Sea and the R/V Gakkel is planned to work at 40 stations situated in the northwestern shelf area.

The R/V Vodyanitsky and the R/V Kolesnikov will visit 5 common stations located along  $34^{\circ}45'$  longitude. Similarly, the R/V Kolesnikov and the R/V Gakkel will have 2 common stations located along the continental slope of the northwestern Black Sea. The R/V Vodyanitsky and the R/V Kolesnikov will also have three intercalibration stations with the Turkish ships the R/V Bilim and the R/V K. Piri Reis.

Figure 2b shows the selected transects for the biochemical measurements carried out by the Soviet ships. There are 36 biochemical stations for R/V Vodyanitsky, 20 for R/V Kolesnikov and 18 for R/V Gakkel. As shown in Figure 2b, some of these stations are the common stations for the intercalibration/intercomparison purposes.

Figure 3a displays CTD stations (a total of 126) which will be visited by the Turkish ships. The R/V Bilim will cover 76 stations within the eastern and central parts of the study area. The R/V K. Piri Reis will work on the western part (60 stations). The R/V Bilim has two intercalibration stations with the R/V Vodyanitsky, and two with the R/V

Kolesnikov. The R/V Bilim and the R/V K. Piri Reis will have 10 common stations.

Figure 3b shows the selected transects for the biochemical stations. There are 33 stations for the R/V Bilim and 27 stations for the R/V K. Piri Reis. The common stations are also indicated in Figure 3b.

Figure 4a shows the CTD stations (a total of 57) which will be covered by the R/V Akademik. As indicated above, there are some stations which will also be visited by other ships (e.g. RV K. Piri Reis, RV Kolesnikov, RV Gakkel).

Figure 4b displays the biochemical stations (a total of 32) studied by the R/V Akademik.

RV Bilim and RV Akademik have been assigned as the mother ships responsible for ship to ship communications during the survey. RV Bilim will be responsible for the communication on the daily operations of the RV Vodyanitsky and RV Kolesnikov. RV Akademik will carry out the same task with the RV Gakkel and RV K. Piri Reis. A Single side band will be assigned for this purpose. Ship to ship communications will be done twice a day at 0600 and 1400 GMT hours.

Starting date of the ships to the survey must be informed to other institutions. Institutions will be responsible to inform the others of the stations occupied by their ships every three days.

TABLE 1

## LIST OF BIOCHEMICAL PARAMETERS

parameters	stations	Amount sample required	depth levels	method & instrument	notes
Dissolved Oxygen (O <sub>2</sub> )	every 3 <sup>rd</sup> st.	300 mL	12 (0-200m)	winkler	(1)
Hyd. sulphide (H <sub>2</sub> S)	every 3 <sup>rd</sup> st.	300 mL	11 (75-1000m)	titration	(2)
Nutrients (NO <sub>3</sub> , o-PO <sub>4</sub> )	selected transects	1 L	14 (0-1000m)	autoanalyzer	(3)
Chlorophyll-a	every 3 <sup>rd</sup> st.		(0-100m)		(5)
(a) in situ			continuous	fluorometer	
(b) water sampling		3 L	5 levels	spectrophotometer	

## Optional Parameters

Diss. Org. Car. (DOC)	selected stations	100 mL	14 (0-1000m)	autoanalyzer	(3)
Part. Org. Car. (POC)	selected stations	10 L	4 (0-500m)	CHN analyzer	(4)
Part. Org. Car. (PON)	selected stations	10 L	4 (0-500m)	CHN analyzer	(4)
Total Suspend. Sediment (TSS)	selected stations	1 L	surface	gravimetry	
Eh & pH	selected stations	300 mL	9 (0-1000m)	pH-meter	(6)
phyto- plankton	selected stations	1 L	surface	microscope	
zoo- plankton	selected stations	1 L	surface	microscope	

Heavy metals	selected stations	1 L	surface	atomic absorption
-----------------	----------------------	-----	---------	----------------------

---

(1) 12 depth levels; 7 of these corresponds to the standard depth levels (0m, 20m, 50m, 75m, 100m, 150m, 200m). The rest will be finer resolution near the oxic/anoxic interface which is predetermined and/or guessed by other means (e.g. by direct oxygen measurements with CTD probe). The depth of 8° C isotherm below the Cold Intermediate Layer might be a reasonable depth level for starting the fine sampling.

(2) At the same stations with the dissolved oxygen and at 11 standard depth levels between 75m and 1000m (75m, 100m, 125m, 150m, 200m, 250m, 300m, 400m, 500m, 750m, 1000m). Additional water samples are taken near the oxic/anoxic interface with finer resolution.

(3) At 14 standard depth levels between 0m and 1000m (0m, 20m, 50m, 75m, 100m, 125m, 200m, 250m, 300m, 400m, 500m, 750m, 1000m).

(4) At 4 depth levels (20m, 100m, 200m, 500m).

(5) At 5 standard depth levels between 0m and 100m (0m, 20m, 50m, 75m, 100m). In the discrete water sampling, standard spectrophotometric method will be employed by using GFC or GFF Whatman glass fiber filters.

(6) At 10 depth levels between 0m and 1000m (0m, 20m, 50m, 100m, 150m, 200m, 300m, 500m, 750m, 1000m).

## TABLE 2

### The Format of a CTD data file

First line: Latitude in Degrees Minutes and Seconds  
Second line: Longitude in Degrees Minutes and Seconds  
Third line: Date and starting time for measurements;  
(In the form of MONTH DAY YEAR HOURS MINUTES)  
FOR EXAMPLE: 09 11 91 14 15  
Fourth line: The total depth at the station (in meters)  
Fifth line: The Secchi disk depth (in meters)  
(In the case of no Secchi disk depth data for the  
station, this line should be a blank line)  
Sixth line: blank  
Seventh line: First line of the data set. Its form is:  
(PRES. (Db), TEMP. (Deg C), SAL. (ppt), SIGMA-T)  
Eighth line: Second line of the data set  
:  
:  
:  
:

The following format will be used for the data

First line: FORMAT(3I2)  
Second line: FORMAT(3I2)  
Third line: FORMAT(5(I2,2X))  
Fourth line: FORMAT(F5.0)  
Fifth line: FORMAT(F4.1)  
Sixth line: FORMAT(1X)  
Seventh line: FORMAT(I4, 3(1X,F7.4))  
Eighth line: "  
:  
:  
:"

In addition to the CTD data files for each station, there must be an ASCII file giving short descriptions for instruments, measurement techniques, the data processing procedure, etc.

TABLE 3

## Ships, Cruise Coordinators and Chief scientists

Nationality	Ship	Chief Scientist	Cruise Coordinator
Bulgaria	R/V Akademik	A. Konsulov & D. Aubrey	Z. Belberov
Romania	None		V. Diaconu
Turkey	R/V Bilim	T. Oguz	U. Unluata
	R/V K. Piri Reis	T. Konuk	U. Unluata
U.S.A.	None		D. Aubrey
U.S.S.R.	R/V Kolesnikov	V. Latun	V. Latun
	R/V Gakkel	unknown	V. Latun
	R/V Vodyanitsky	unknown	V. Latun

TABLE 4

Equipment available in the ships for  
HydroBlack-1991

Ship	CTD probe	Rosette sampler	Winkler Tit. syst.	Auto- analyzer	Fluoro- meter
RV BILIM	SeaBird SBE-9	General Oceanics	semi-automatic (Hydro-Bios)	Technicon multichan.	Navitronic Q-200
RV K. PIRI REIS	Seabird SBE-9	General Oceanic	semi-automatic (Brand)	Skalar multichan.	not available
RV AKADEMIK	Neil Brown	not available	conventional lab. technique	not available	not available
RV VODYA- NITSKY	Seabird SBE-9	?	?	?	?
RV KOLESNIKOV	SBE-19 or SBE Sealogger	?	?	?	?
RV GAKKEL	SBE-19 or SBE Sealogger	?	?	?	?

TABLE 5

Starting dates to HydroBlack-1991 survey for the ships

R/V BILIM	September 1, 1991
R/V K. PIRI REIS	September 5, 1991
R/V AKADEMIK	September 3, 1991
R/V KOLESHNIKOV	?
R/V GAKKEL	?
R/V VODYANITSKY	?



**APPENDIX III:**  
**CTD DESCRIPTIONS**

## HYDROPHYSICAL SOUNDING COMPLEX MHI 4102 (ISTOK)

### TECHNICAL CHARACTERISTICS

The device has the following data channels:

- temperature data channel
- el.conductivity data channel
- hydrostatic pressure data channel
- channel of control code formation (pilot channel)

Channel	Range	Sensitivity	Accuracy	Output Code
Temperature	-2-(+35)°C	0.0025°C	P=0.95, $\pm 0.025^\circ\text{C}$	binary, 14 - digit
Conductivity				
(1st subrange)	1.5-5.5 S/m	0.00025 S/m	P=0.95,	14 binary,
(2d subrange)	2.5-6.5 S/m	$\pm(0.0002+3*10^{-5})$ S/m		14 - digit
Hydrostatic	0-60 MPa	0.025%*	P=0.95, binary,	
	(Pmax)	$\pm 0.5%*(Pmax)$	consecutive	
		13 - digit		

Time of each parameter measurements is not more than 0.0625s. Discontinuity of each parameter measurements is not more then 0.25s. Heat inertia of the initial temperature-transformer-meter is not more then - 0.05s. Maximum lowering depth - 6000m

Dimensions of the device:

diameter - 600mm

height - 820mm

weight - 100kg

Input voltage  $220 \pm 20\text{V}$ ,  $50 \pm 25\text{Hz}$

Required power 70Watt

Communication is provided by the carrying single cable (length 6,500m)

Environmental temperature - (-2)-(+40)°C

Relative humidity - up to 80% by 27°C

16 sample bottles are attached to the device. Single bottle volume is 1 l.

### Data Recording

- binary and decimal code reflection on the informational panel;
- the information is carried to a personal computer.

Researcher : MHI, UkSSR Academy of Sciences, L.A.Koveshnikov.

The observations of the Secchi disk depth were performed with help of the standard white disk ( 0.3m diameter). Researcher : MHI, UkSSR Academy of Sciences, B.N.Krashennnikov.

## CTD UNDERWATER UNIT SeaBird SBE 9

### TECHNICAL CHARACTERISTICS

The SBE 9 underwater units include temperature, conductivity and pressure sensors. Resultant data in Manchester Code is transmitted to the Deck unit. Twelve ASCII HEX characters representing six bites are transmitted per CTD scan.

The format for CTD scan is :

tttccccpppp

ttt four HEX characters representing 2 bytes of temperature data  
cccc four HEX characters representing 2 bites of conductivity data  
pppp four HEX characters representing 2 bites of pressure data.

Sensor	Range	Resolution	Accuracy	Response Time
Temperature	-5 +35 deg C	0.0003 deg C	+/- 0.003 deg C	0.082 sec (0.5 m/sec drop) 0.070 sec (1.0 m/sec drop)
Conductivity	0-7 S/m	0.00004 S/m	+/- 0.0004 S/m	0.084 sec (0.5 m/sec drop) 0.070 sec (1.0 m/sec drop)
Depth	0-6000 m	0.004 %	+/- 0.02 %	0.001 sec

Weight: 24 kg in air , 15 kg in water

Size: 1.1 m x 0.2 m x 0.3 m

Communication is provided by single cable with length 7000m - Akademik, 1860 m - Bilim and 2200 m -Piri Reis.

## CTD UNDERWATER UNIT SeaBird SBE 19

### TECHNICAL CHARACTERISTICS

The SBE 19 underwater units include temperature, conductivity and pressure sensors. Data were stored in Random Access Memory, and uploaded to a microcomputer on board the ship.

Sensor	Range	Resolution	Accuracy	Response Time
Temperature	-5 +35 deg C	0.001 deg C	0.01 deg C/mo.	
Conductivity	0-7 S/m	0.0001 S/m	+/- 0.001 S/m/mo.	
Depth	0-2000 m	0.05 %	+/- 0.5 %	

## HYDROPHYSICAL SOUNDING COMPLEX "HYDROZOND".

### TECHNICAL CHARACTERISTICS

The device has the following data channels:

- temperature data channel
- el.conductivity data channel
- hydrostatic pressure data channel

Channel	Range	Sensitivity	Accuracy	Output Code
Temperature	-2-(+32)°C	0.01°C	P=0.95, ±0.03°C	binary, 12 digits
-----				
Conductivity				
(1st subrange)	0.5-3.5 S/m	0.001 S/m	P=0.95,	binary, 12 digits
(2nd subrange)	3.5-6.5 S/m	±(0.0035) S/m		
-----				
Hydrostatic	0-3.8 MPa	0.01MPa	±0.04MPa	binary,
	3.8-19.2MPa	0.01MPa	±0.2MPa	consecutive
	19.2-60.0MPa	0.02MPa	±0.6MPa	12 digits

Time of each parameter measurements is not more than 0.064s. Discontinuity of each parameter measurements is not more then 0.32s. Heat inertia of the initial temperature-transformer- meter is not more then - 0.5s. Maximum lowering depth - 6000m

Dimensions of the device:

diameter - 601mm

height - 736mm

weight - 63kg

Input voltage - 220 ÷ 20V , 50 ÷ 25Hz

Required power - 300Wt

Communication is provided by the carrying single cable (length 4.000m)

Environmental temperature - (-2)-(+40)°C

Relative humidity - up to 80% by 27°C

24 sample bottles are attached to the device. Single bottle volume is 1 l.

### Data Recording

- 
- binary and decimal code reflection on the informational panel;
  - the information is carried to a personal computer.

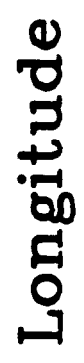
Researcher : SOIN, UkSSR Academy of Sciences, L.V.Matsokin.

The observations of the Secchi disk depth were performed with help of the standard white disk ( 0.3m diameter).

Researcher : SOIN, UkSSR Academy of Sciences, V.V.Sidelnikov.

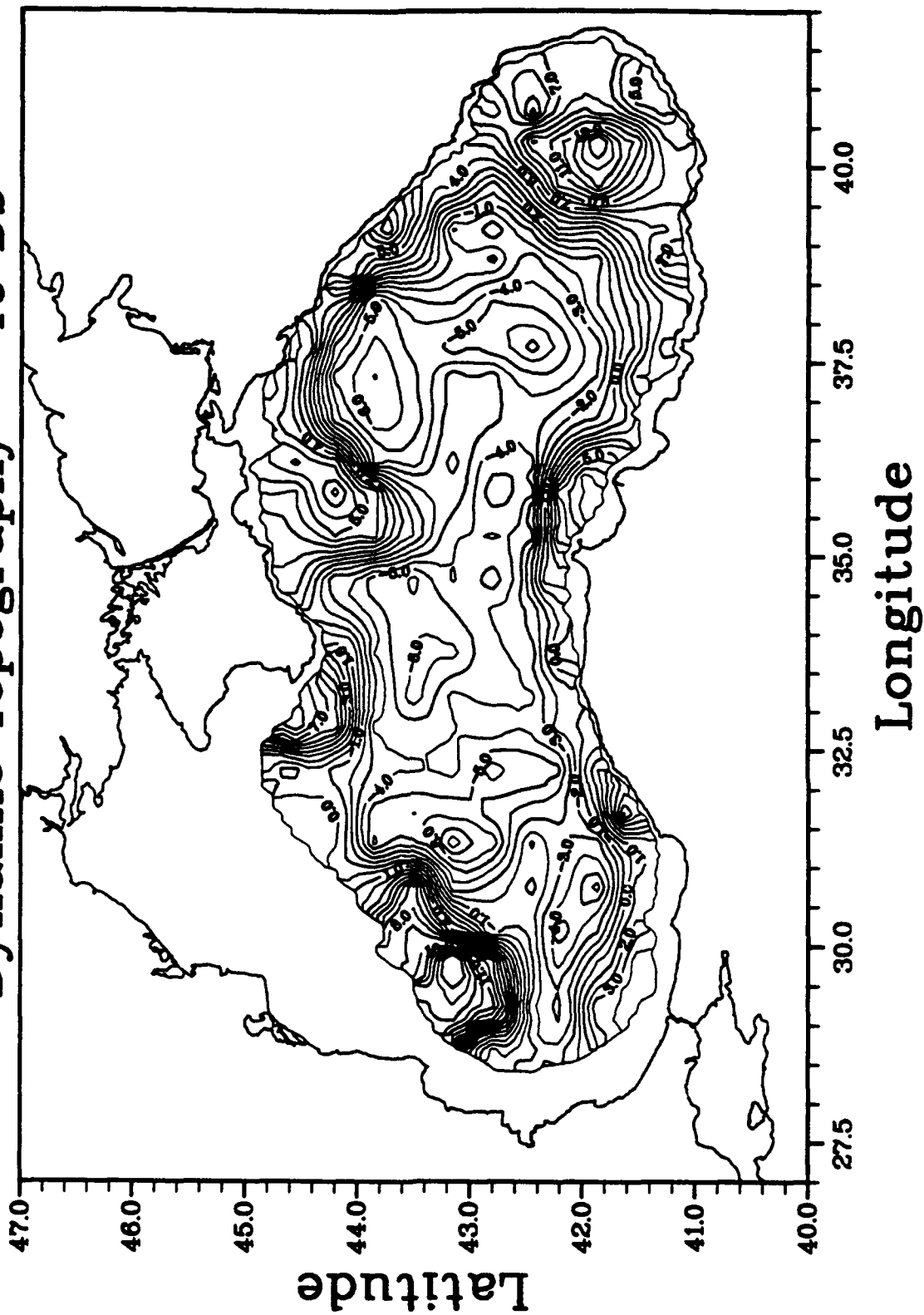
**APPENDIX IV:**  
**DYNAMIC HEIGHTS REFERENCED TO 900 db**  
**Intercalibrated Results**

# Longitude

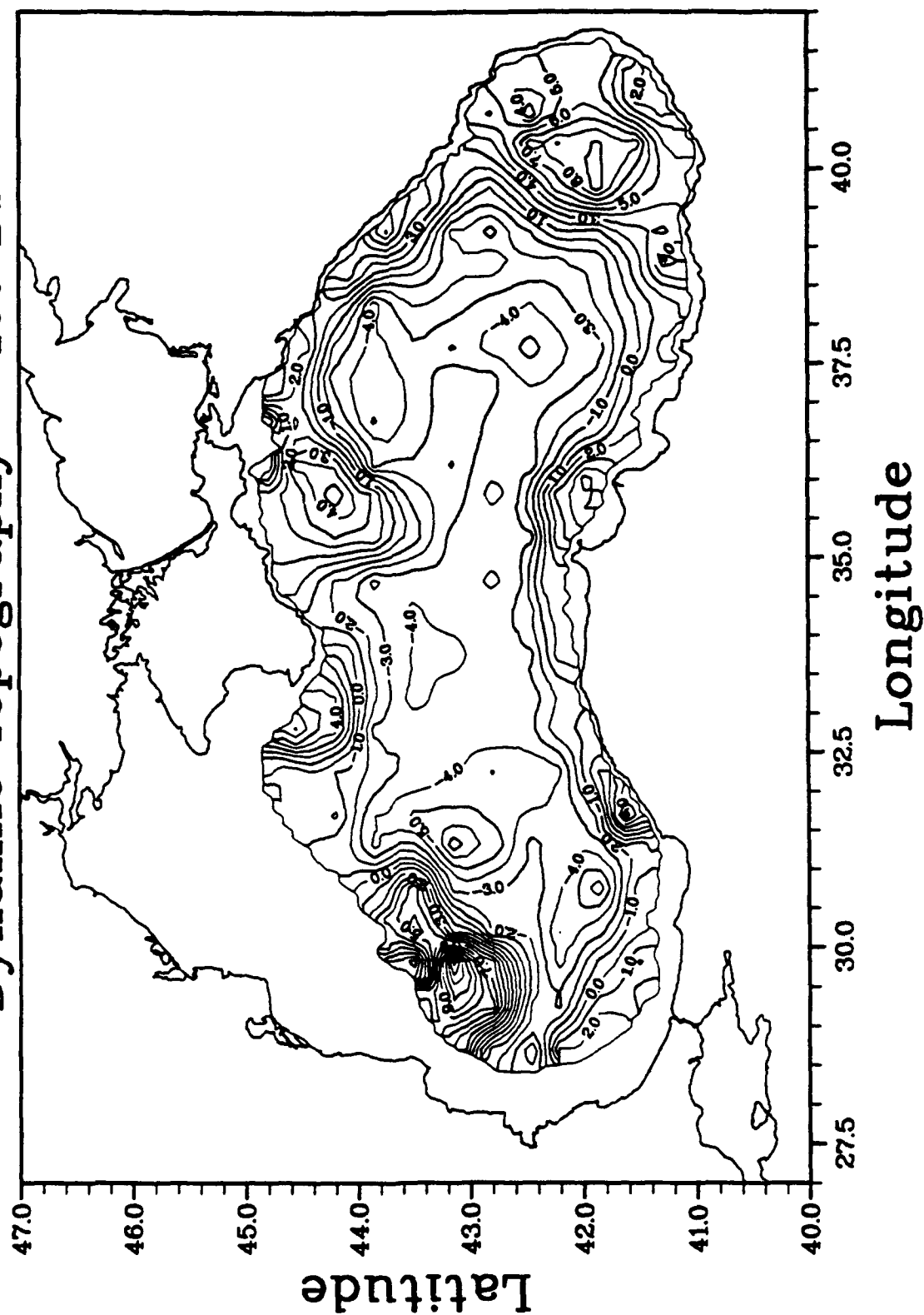
[illegible]



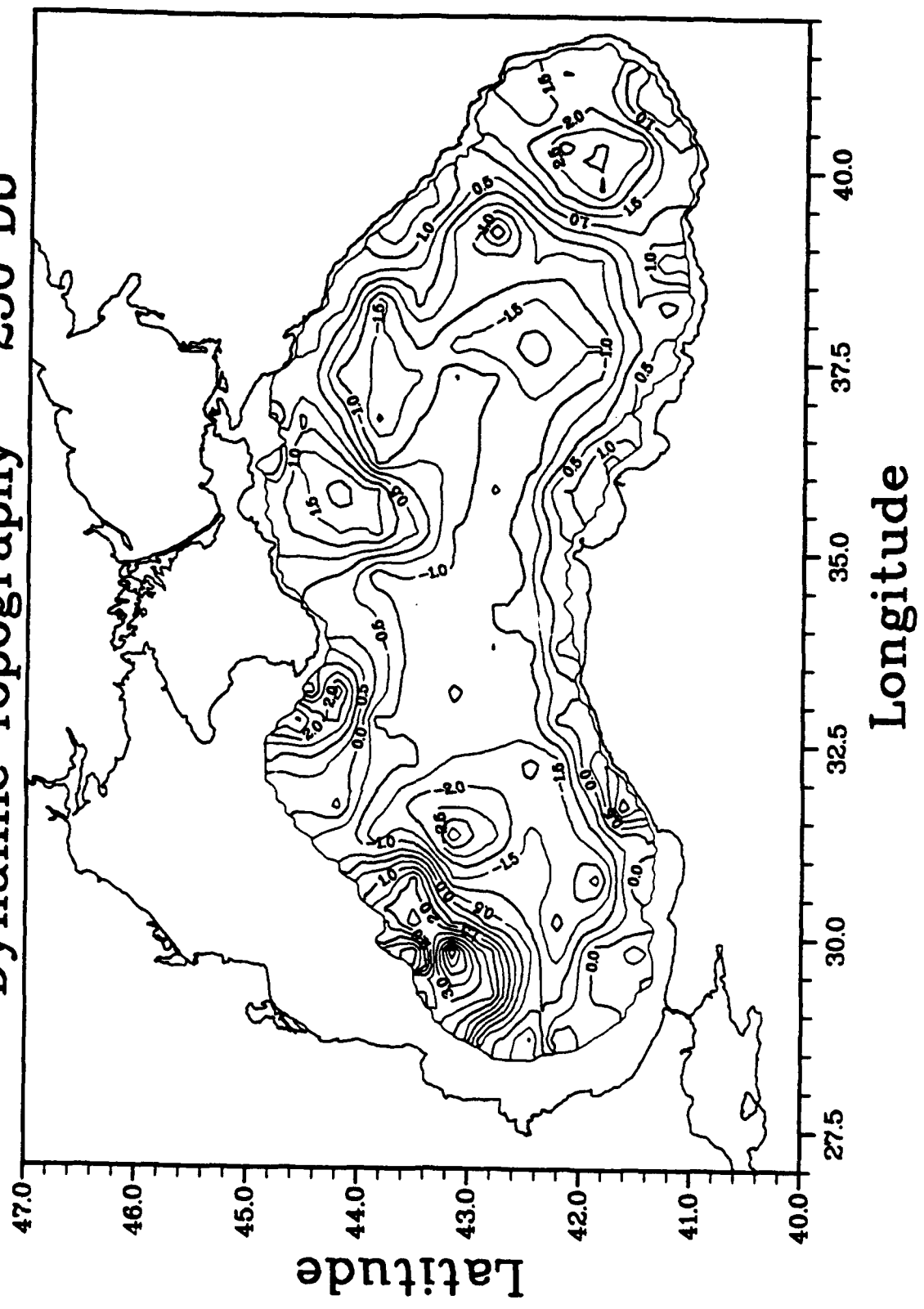
# Dynamic Topography - 40 Db



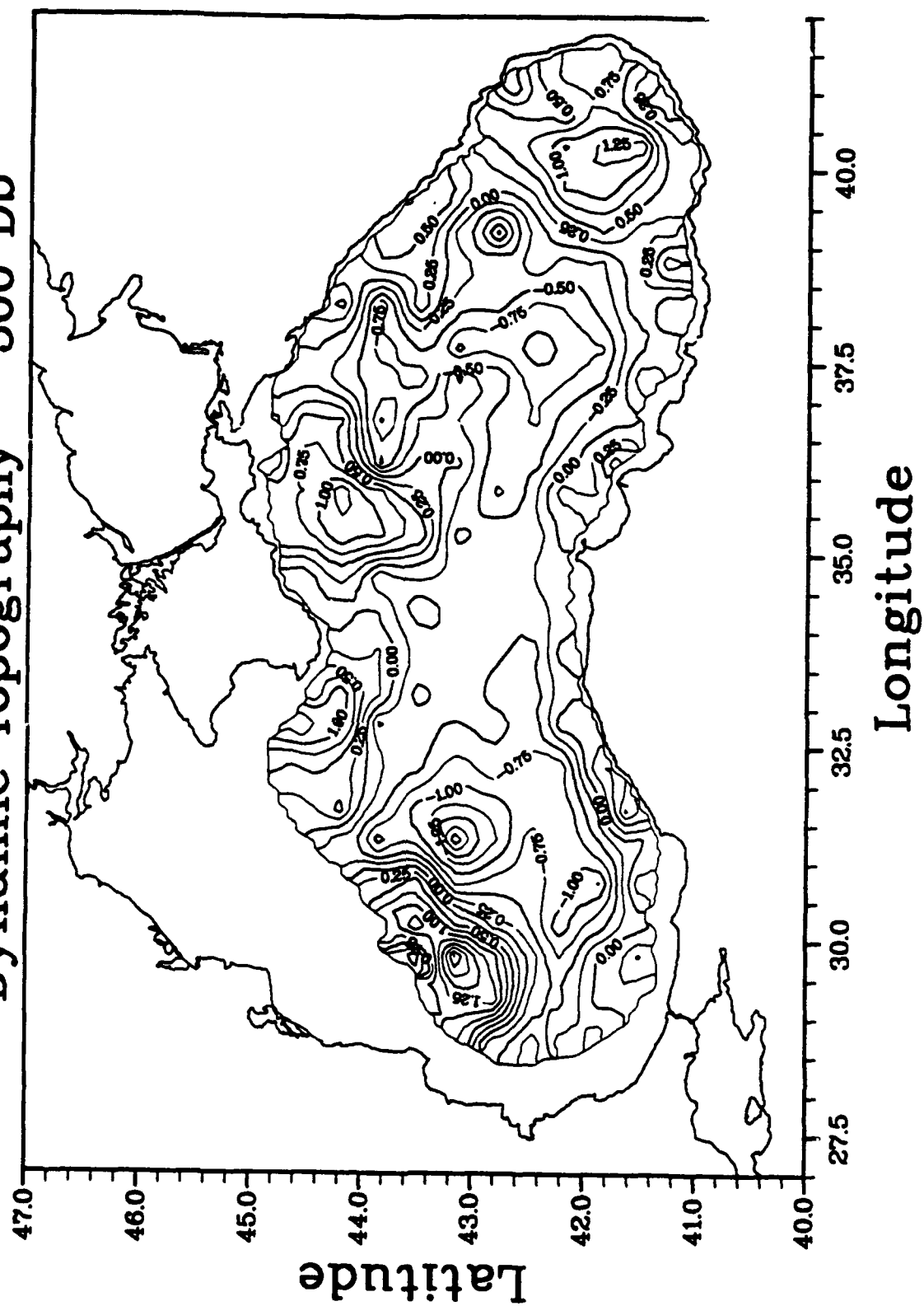
# Dynamic Topography - 100 Db



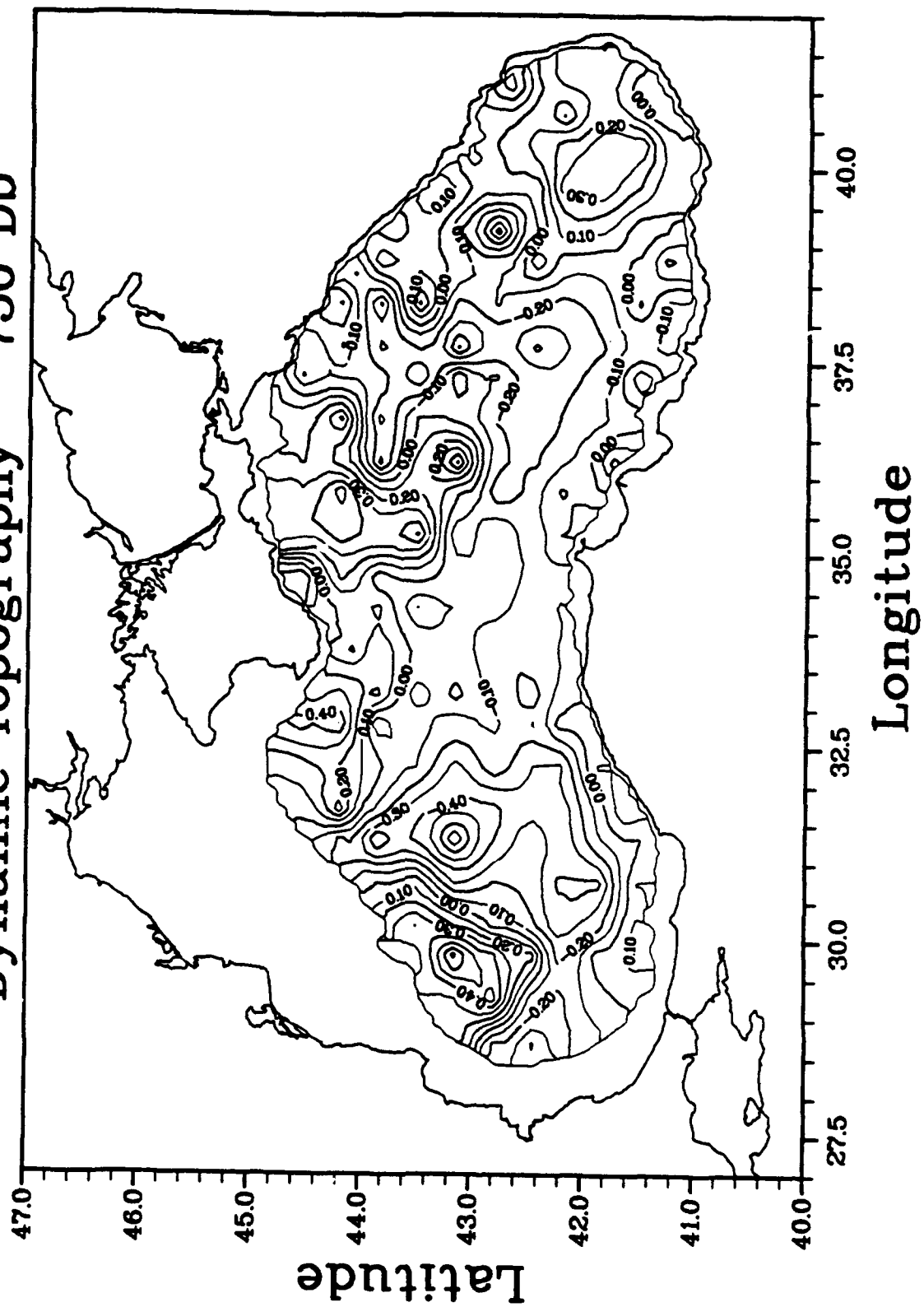
# Dynamic Topography - 250 Db



# Dynamic Topography - 500 Db



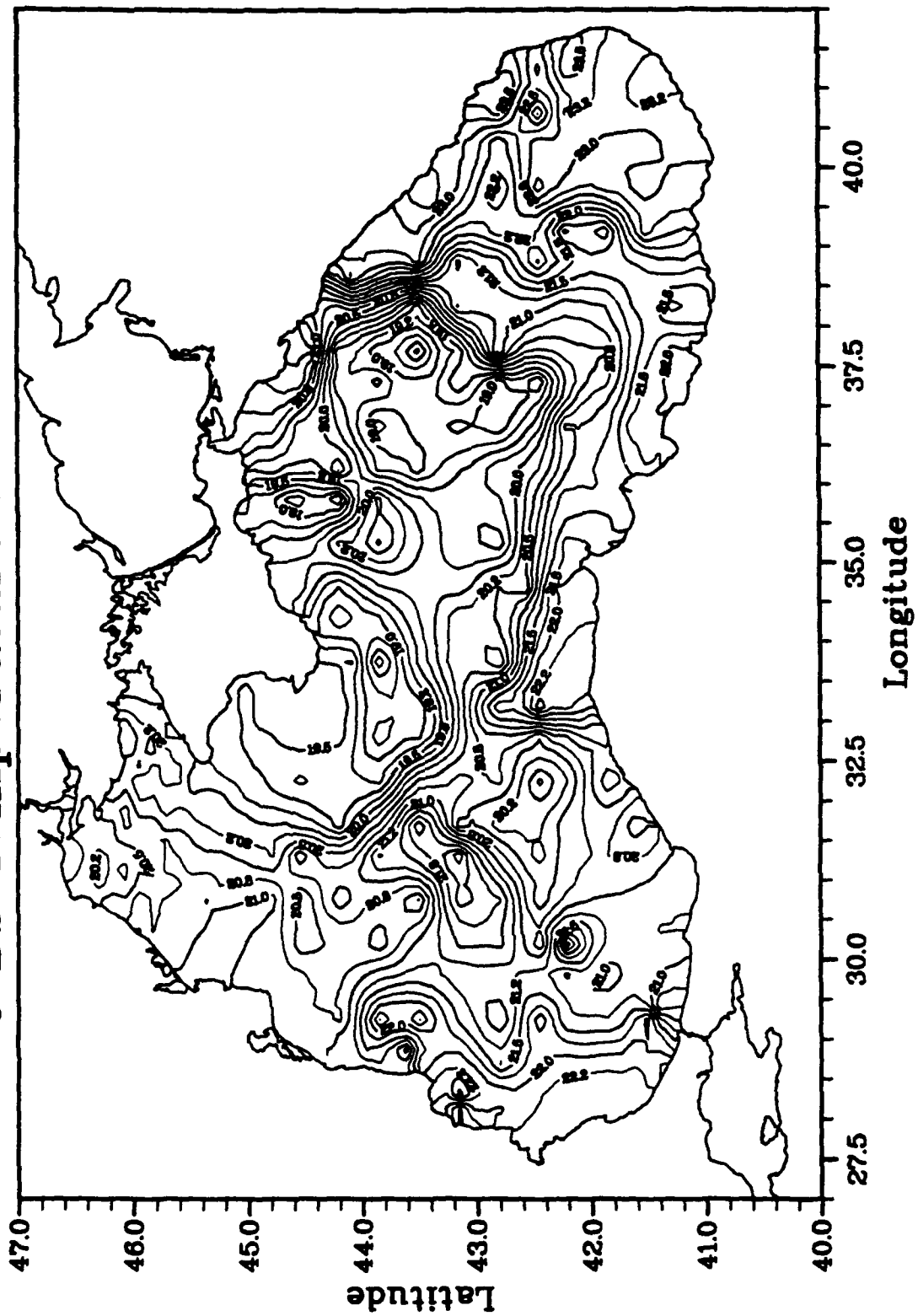
# Dynamic Topography - 750 Db





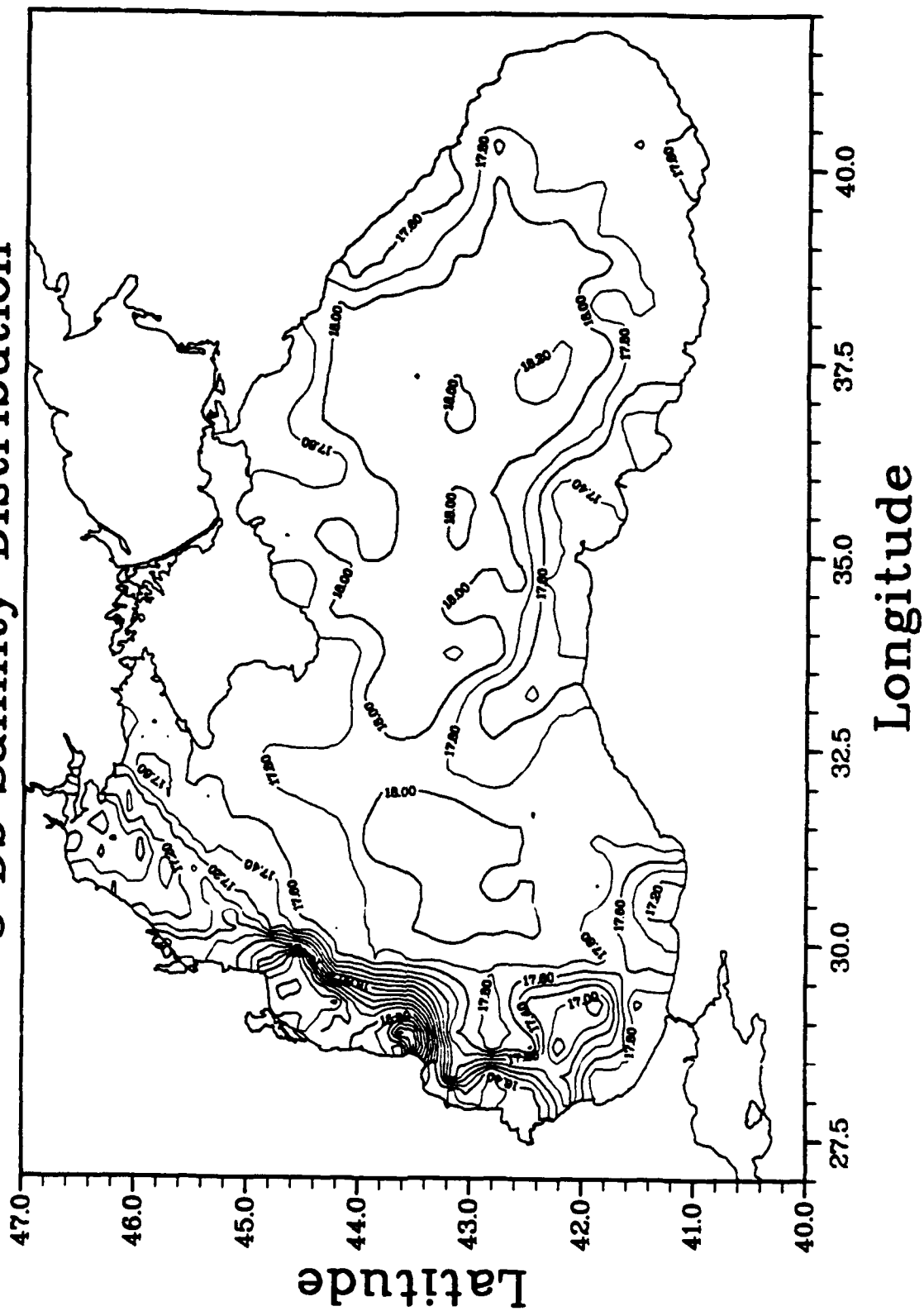
**APPENDIX V:**  
**SAMPLE SECTIONS OF SALINITY, TEMPERATURE, AND**  
**DENSITY**  
**Intercalibrated Results**

## 5 Db Temperature Distribution

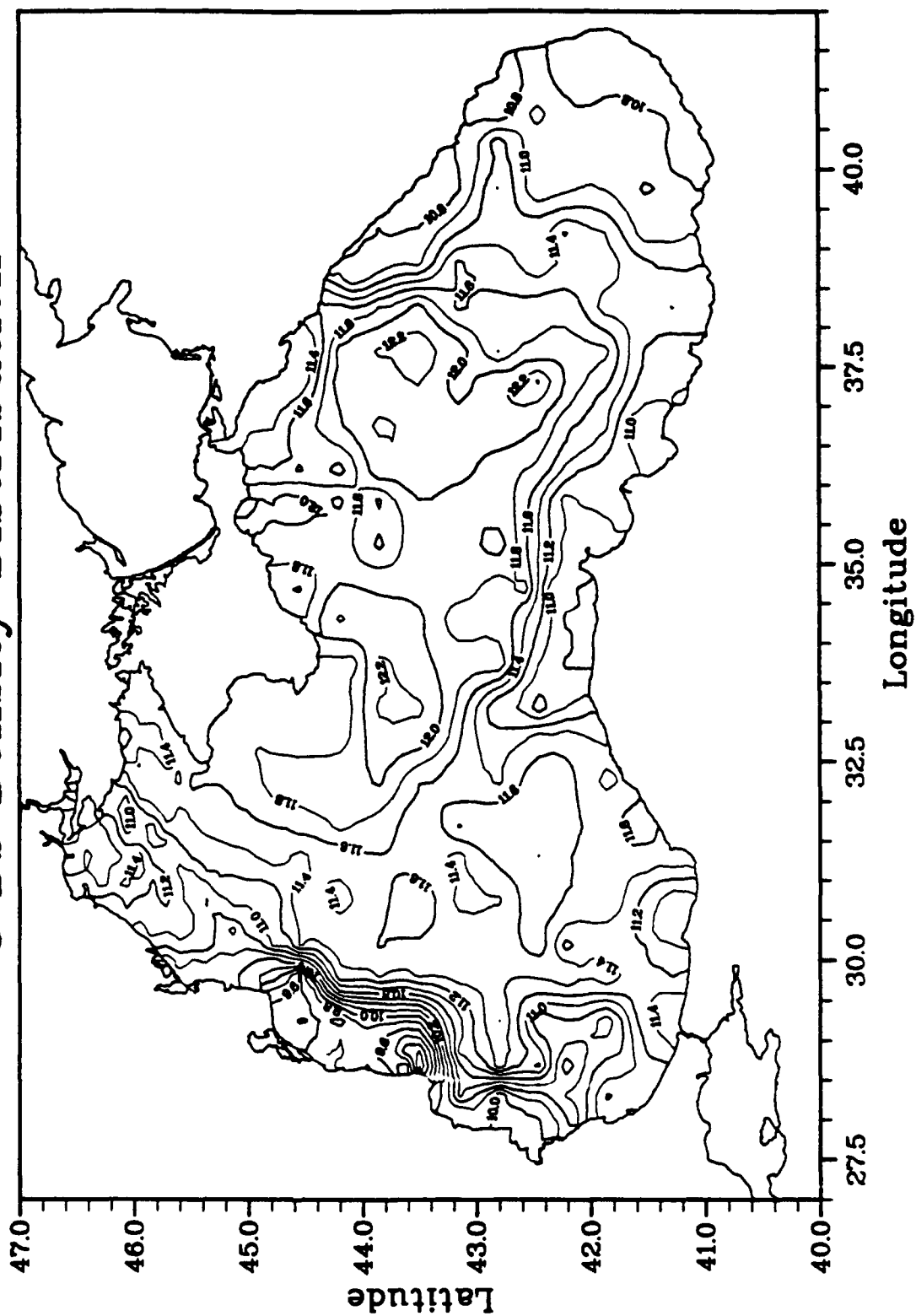




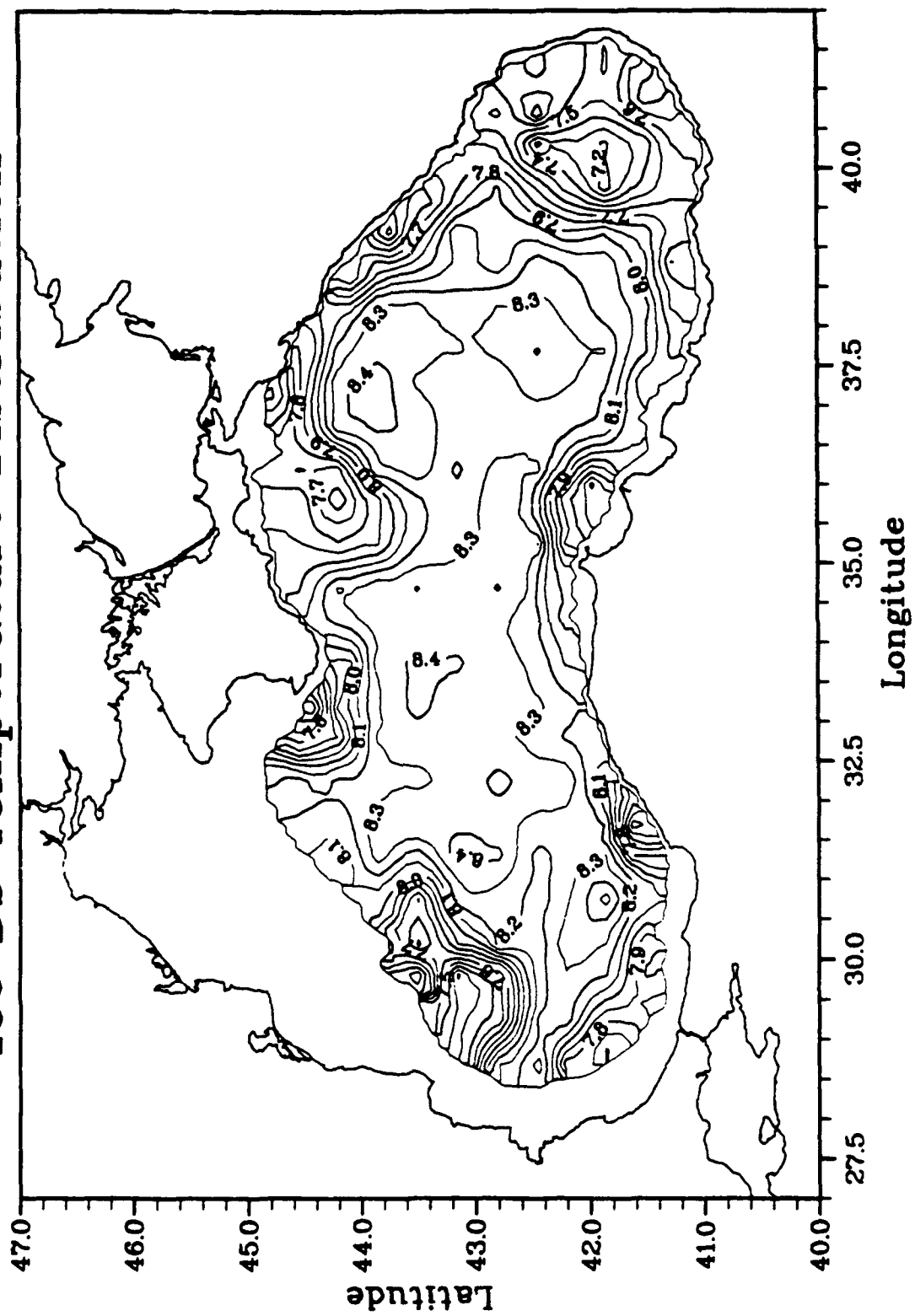
## 5 Db Salinity Distribution



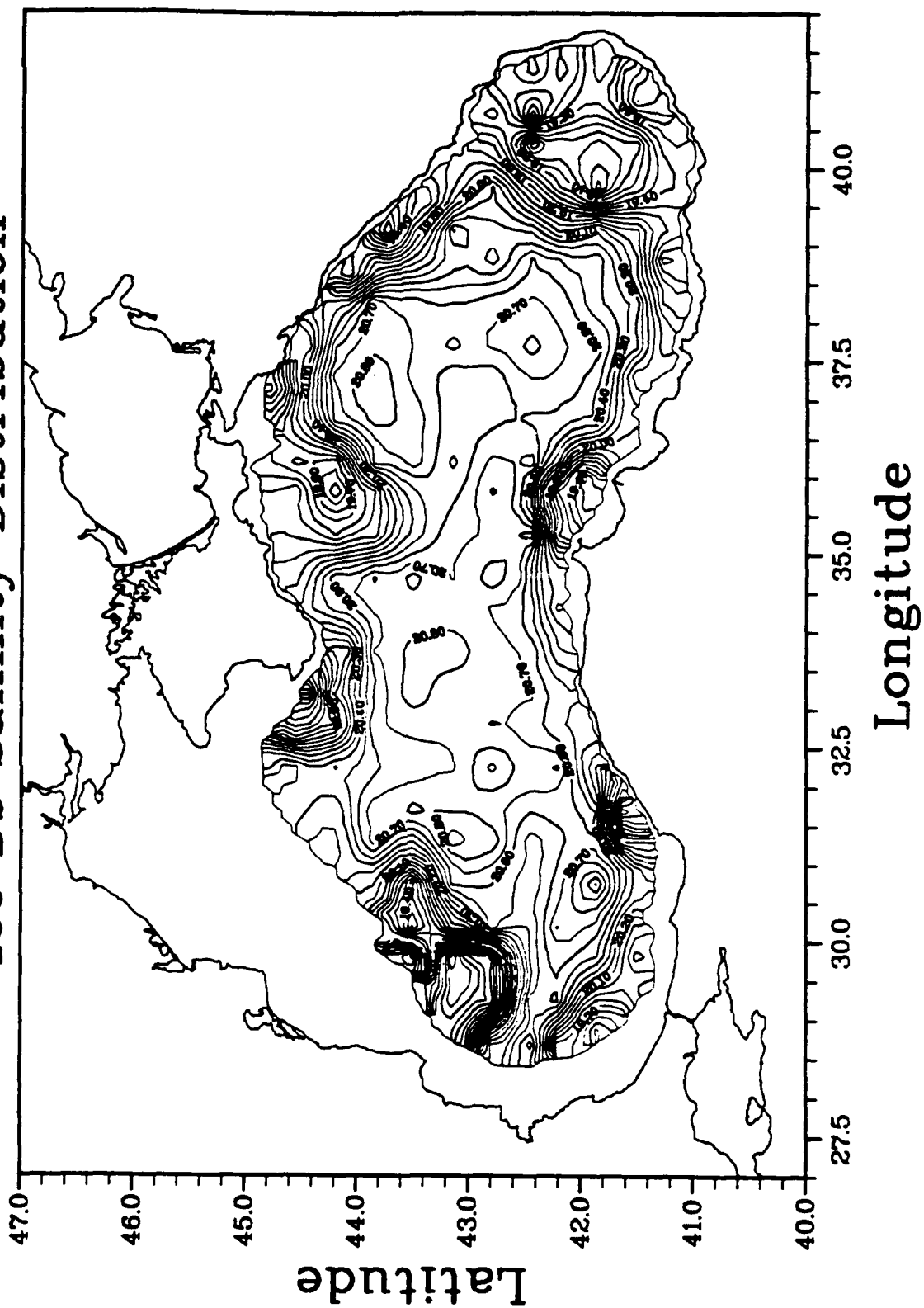
# 5 Db Density Distribution



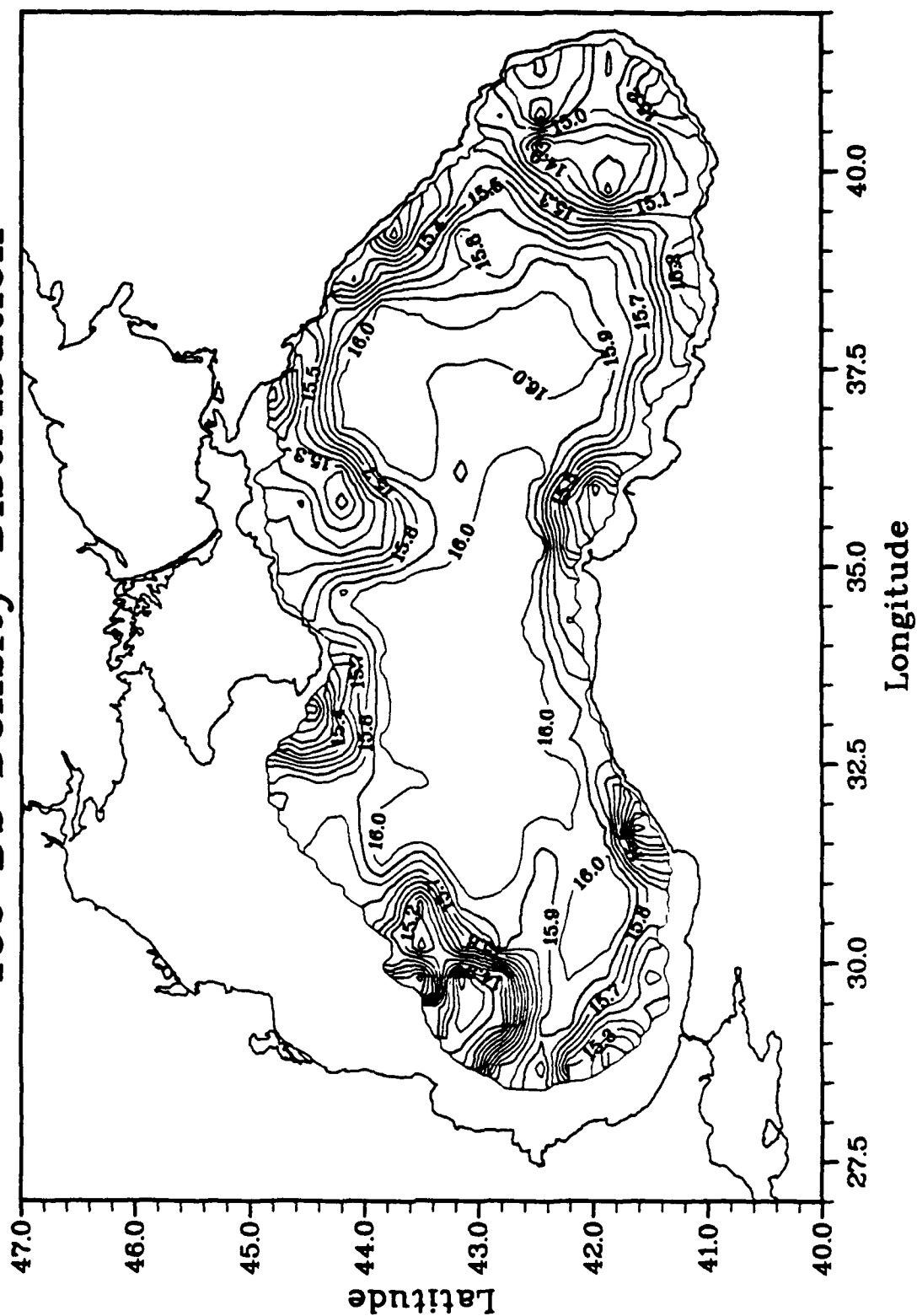
# 100 Db Temperature Distribution



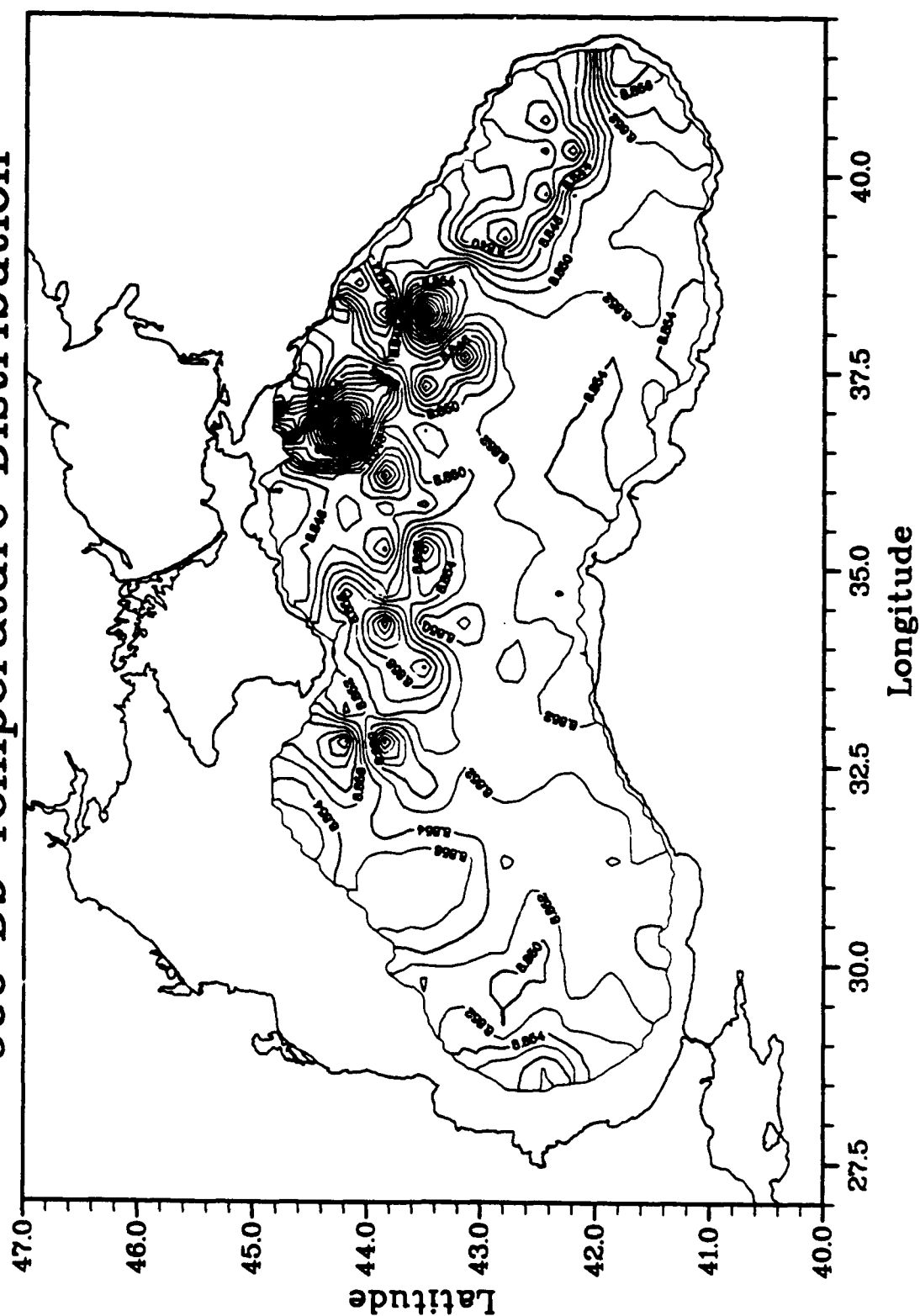
# 100 Db Salinity Distribution



# 100 Db Density Distribution

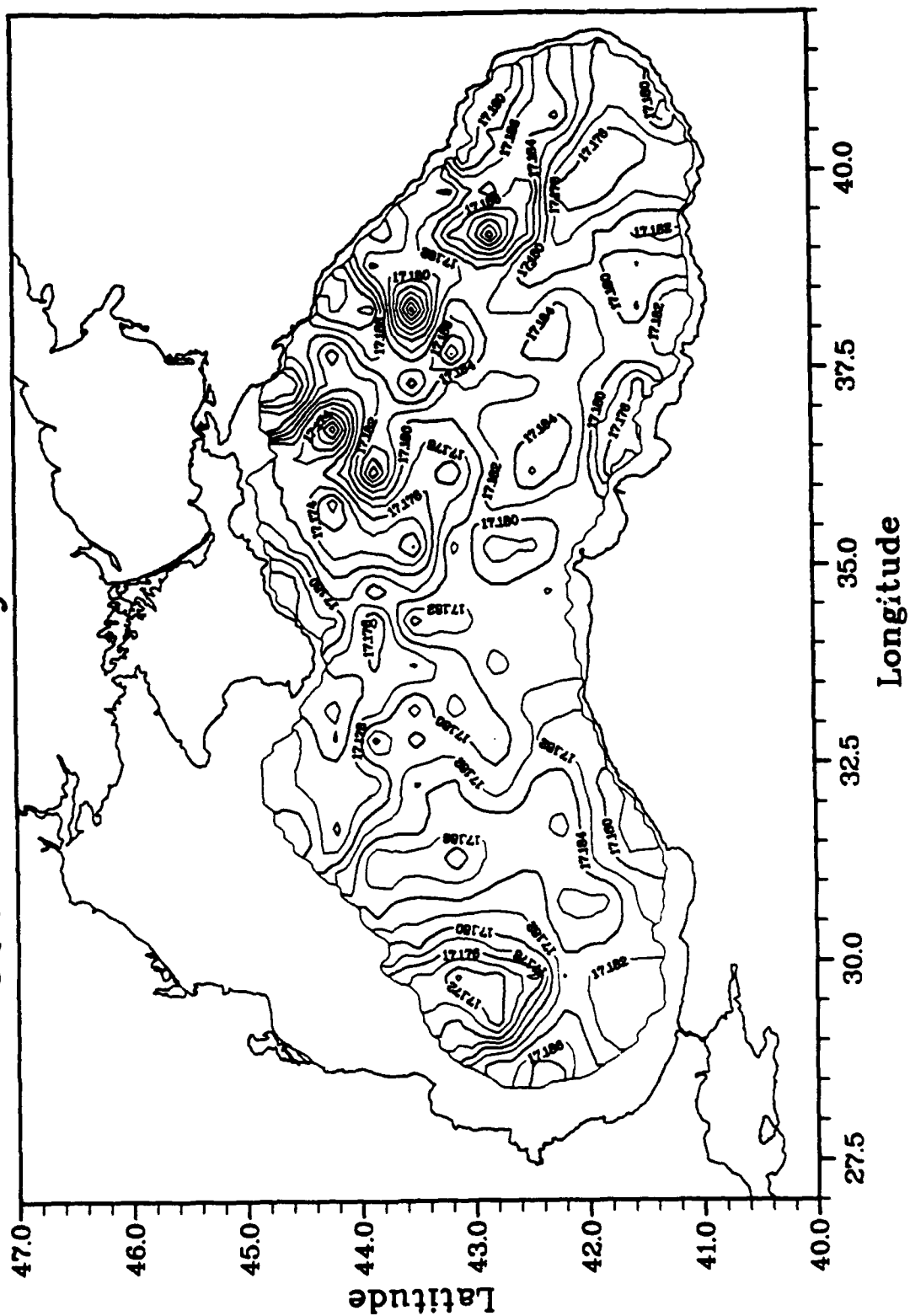


# 900 Db Temperature Distribution



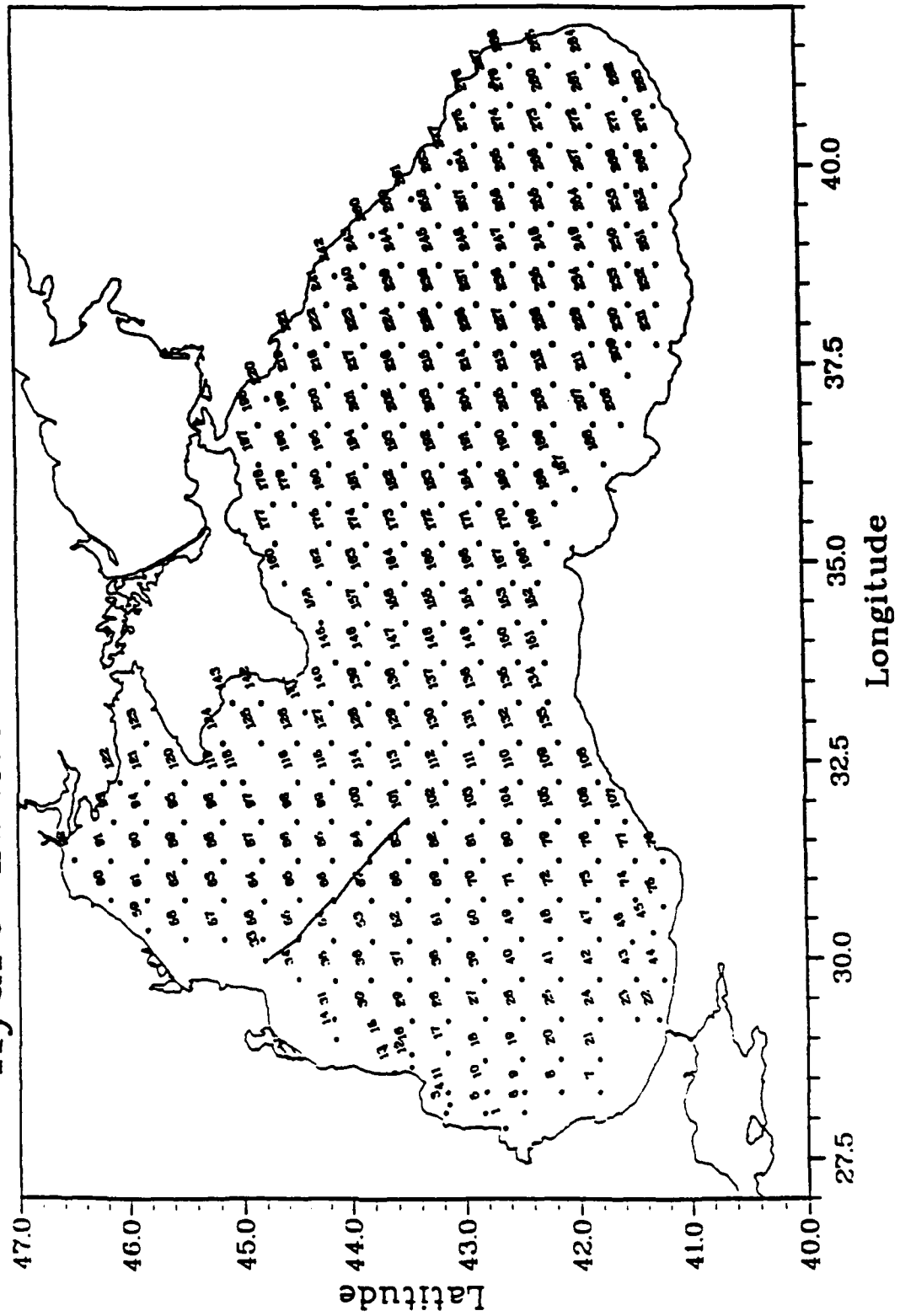


# 900 Db Density Distribution

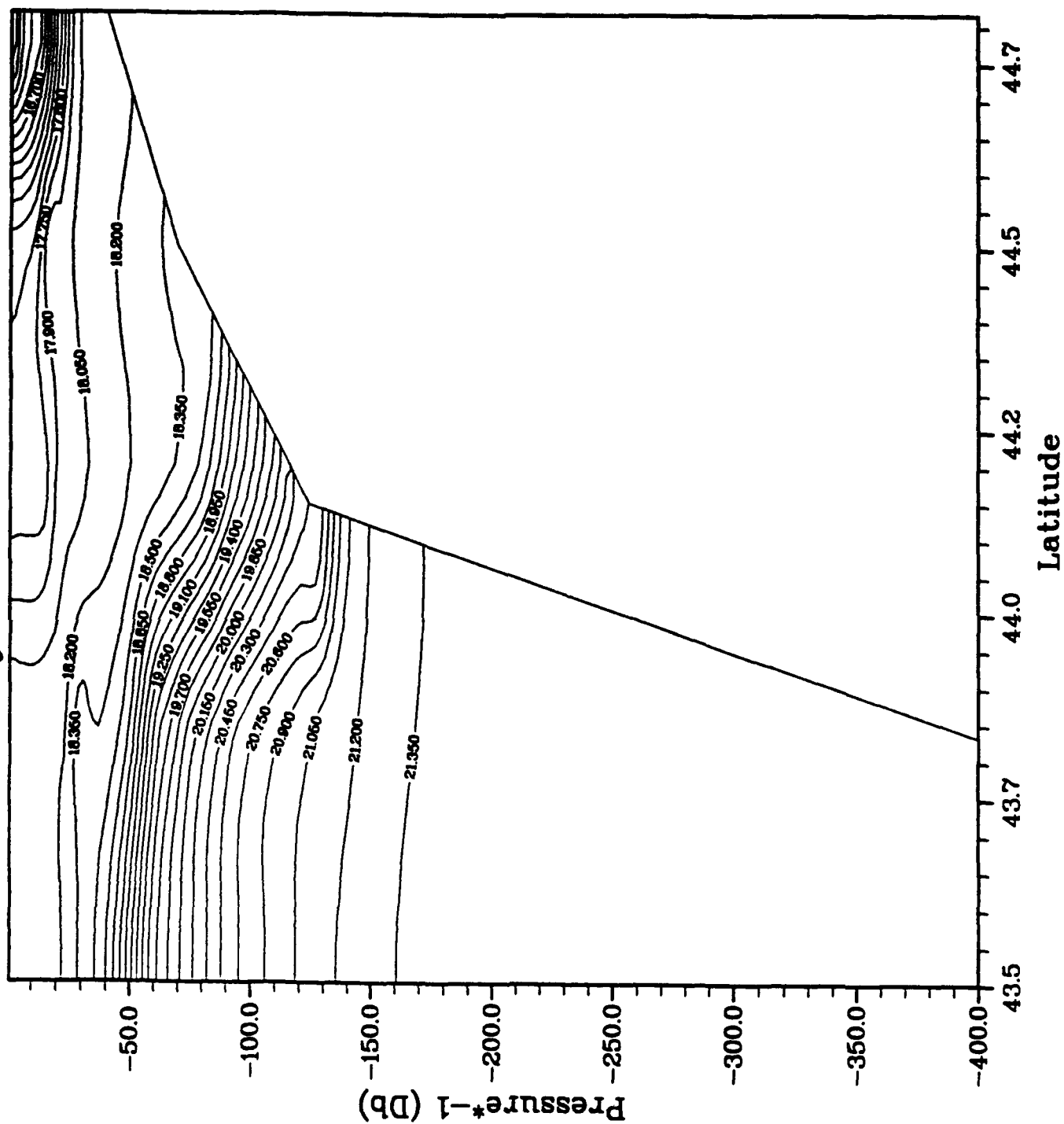




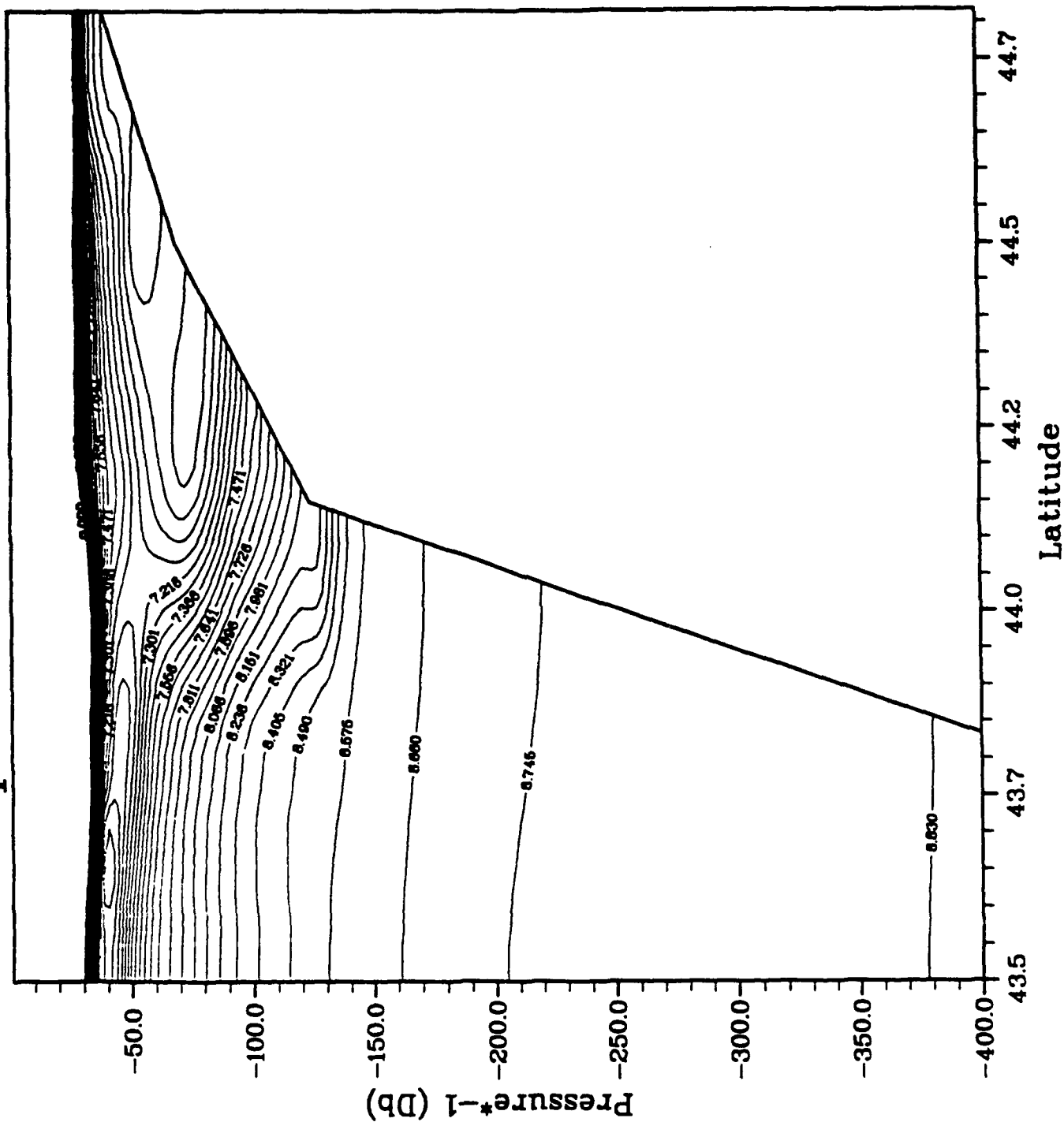
# Hydro-Black 1991 Station Network



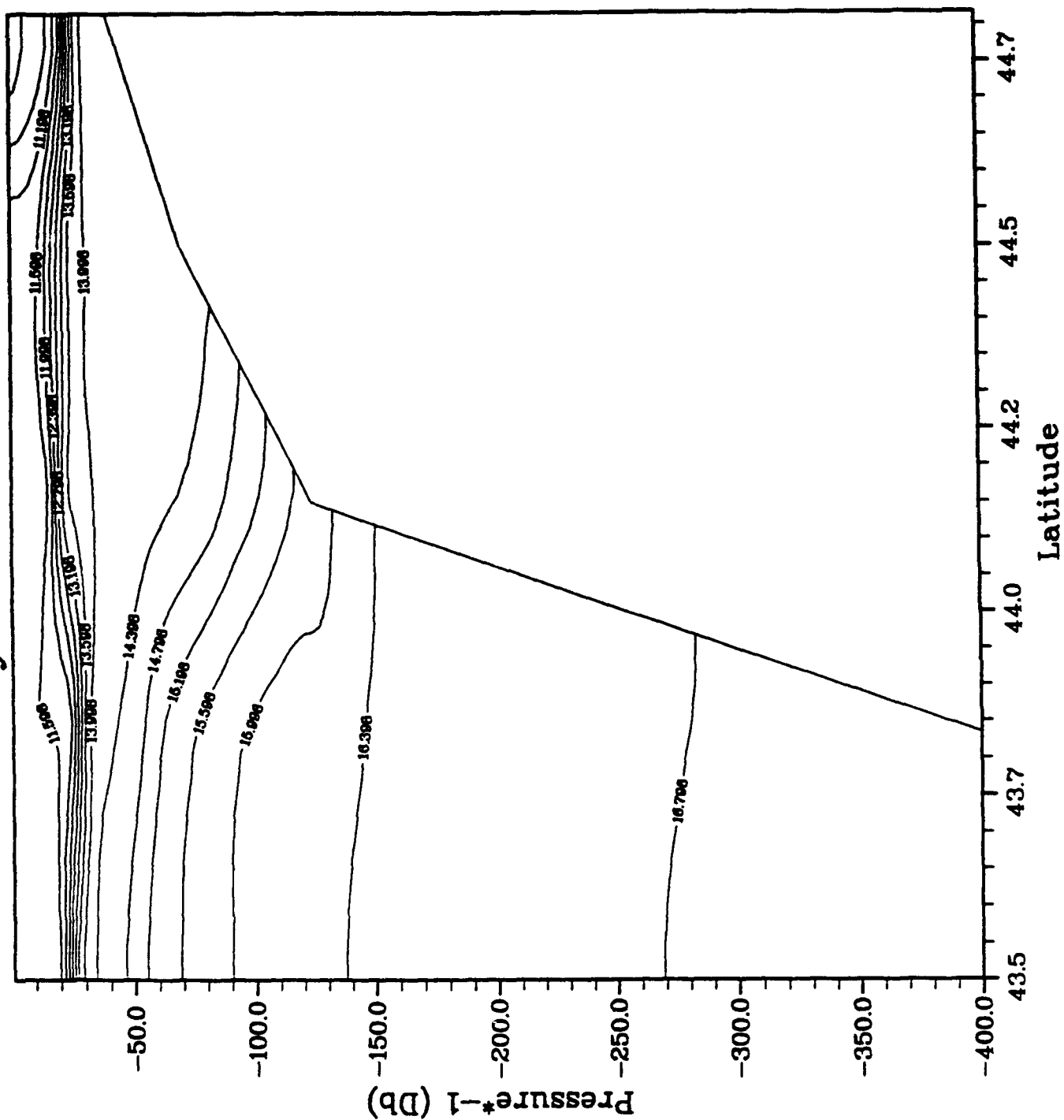
# Salinity: Stations 101 - 33



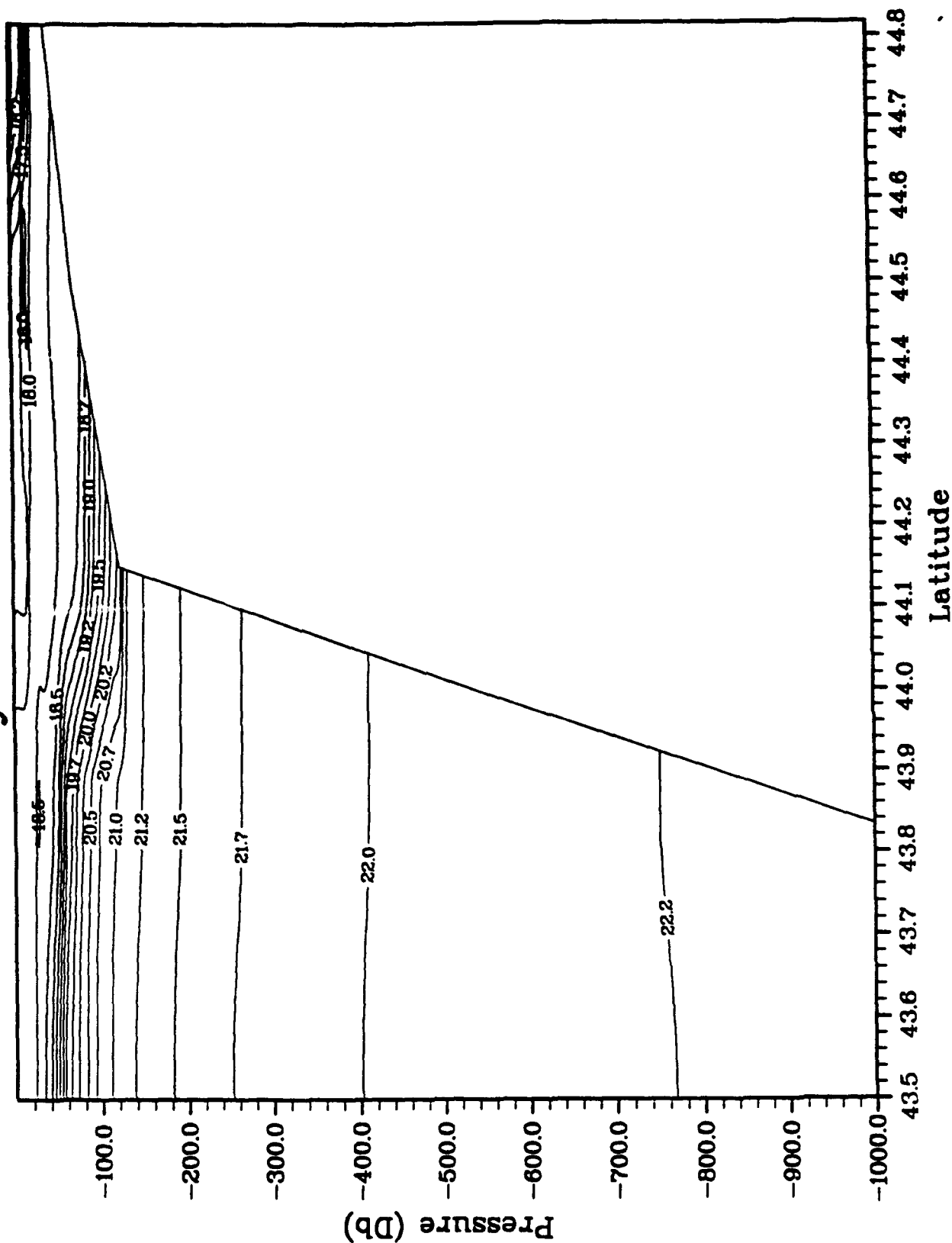
# Temperature: Stations 101 - 33



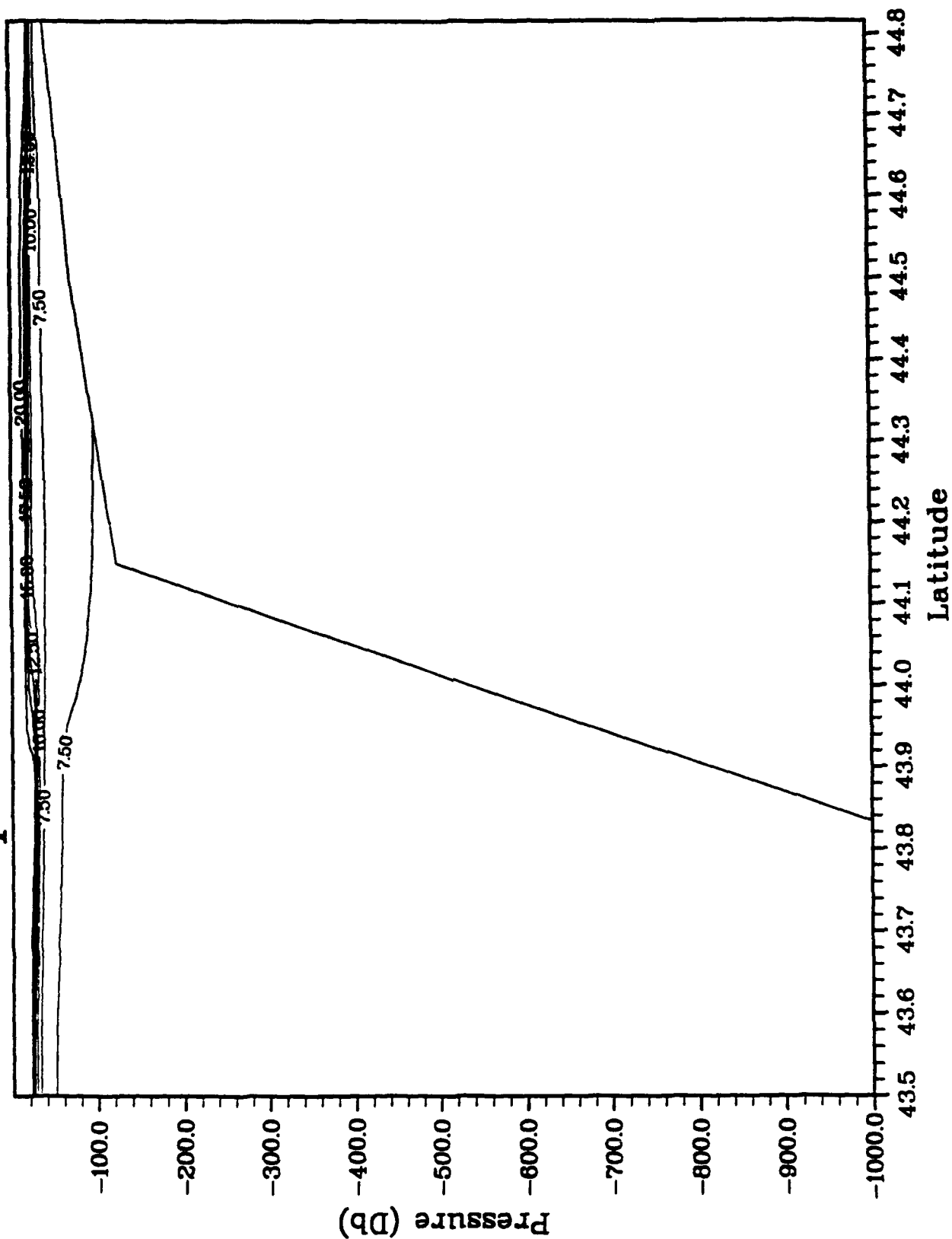
# Density: Stations 101 - 33



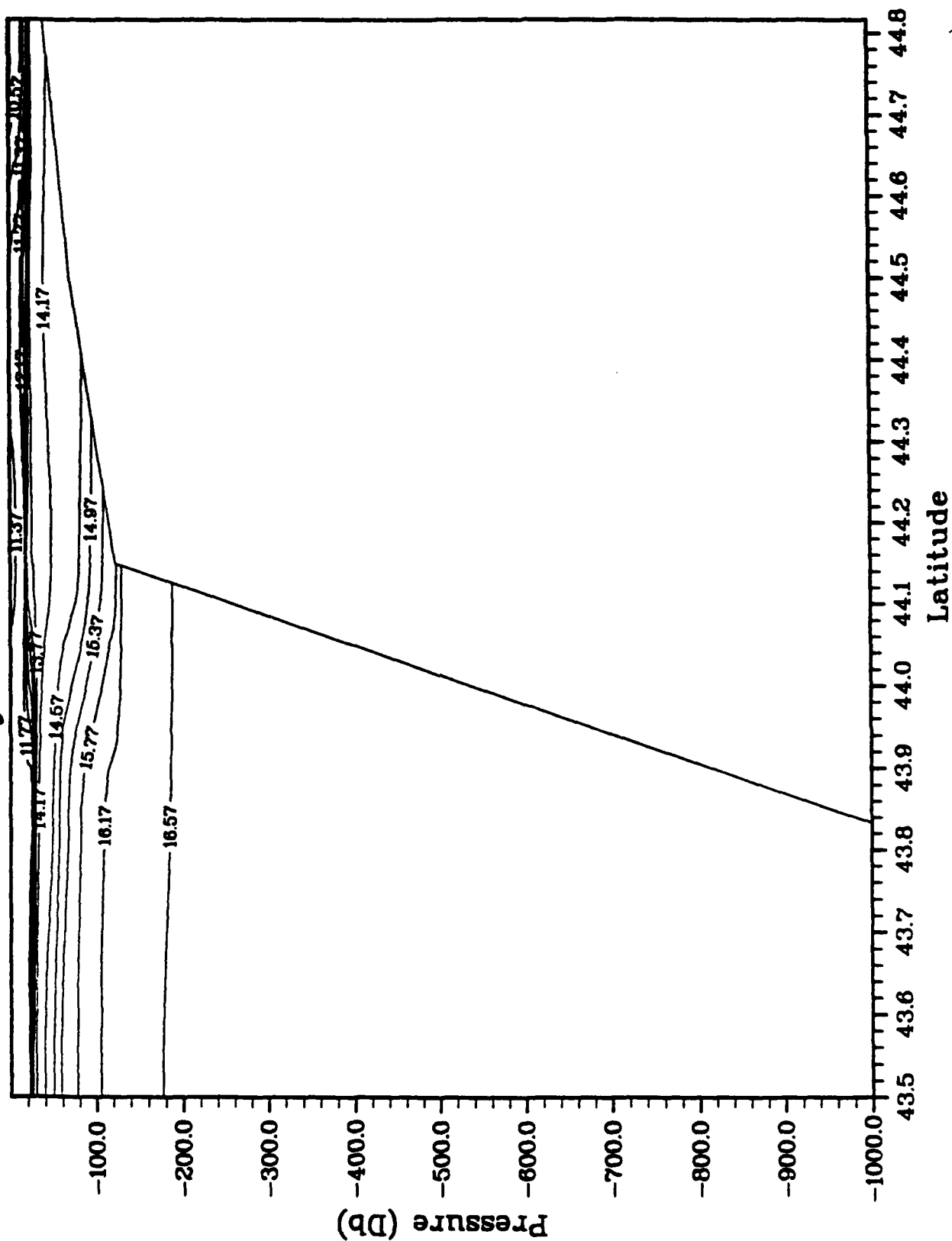
# Salinity: Stations 101 - 33



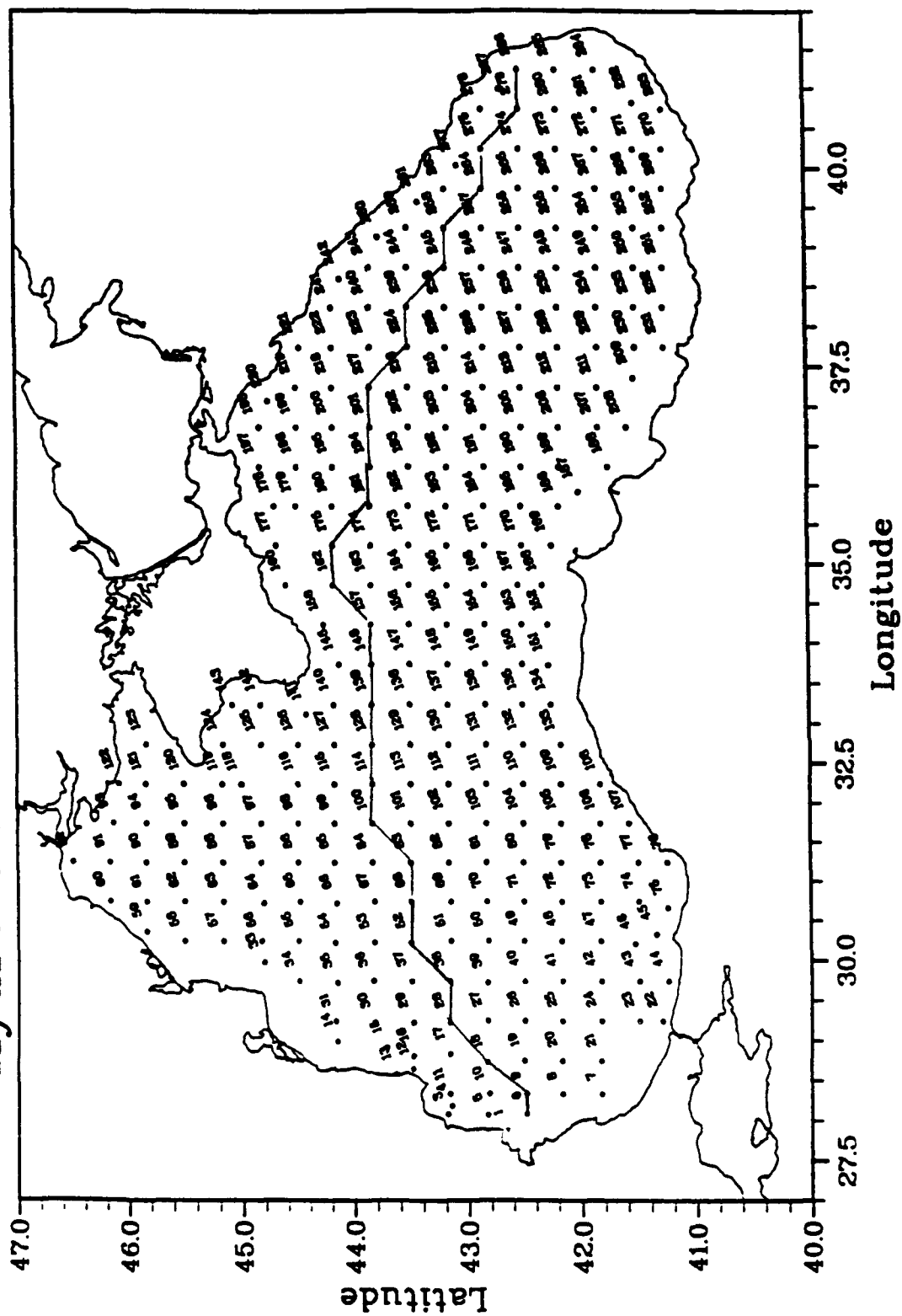
# Temperature: Stations 101 - 33



# Density: Stations 101 - 33

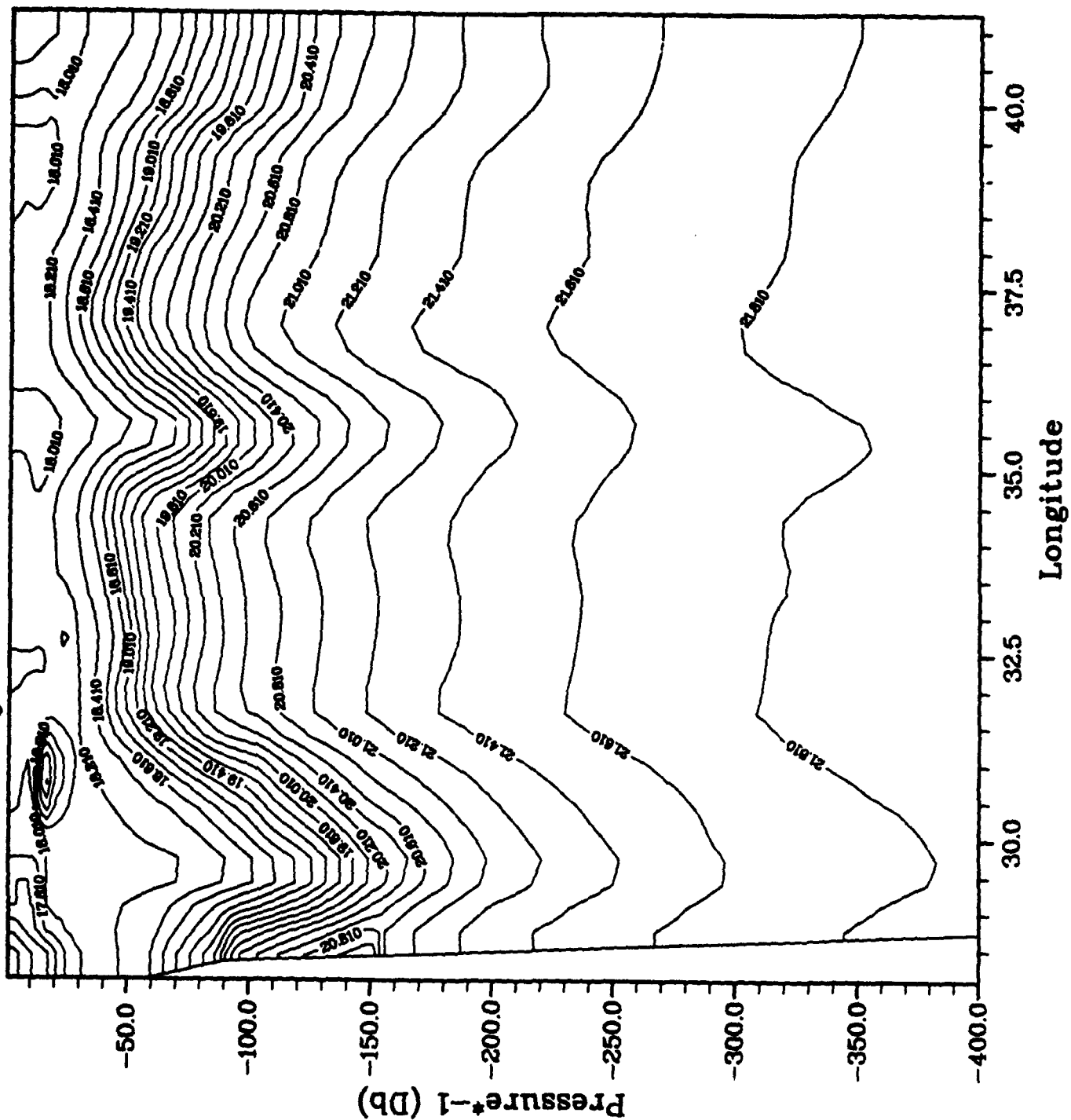


# Hydro-Black 1991 Station Network

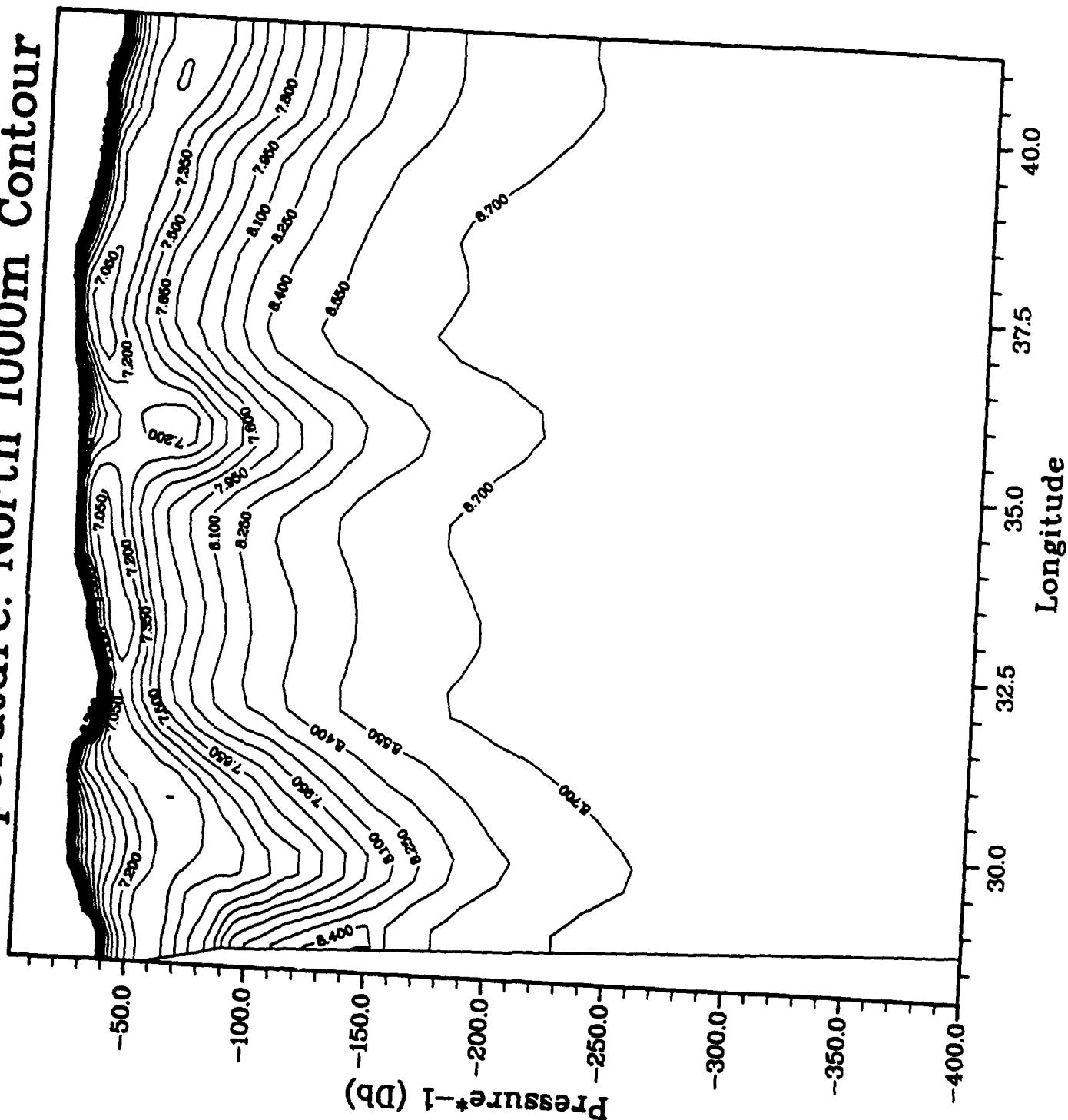




# Salinity: North 1000m Contour

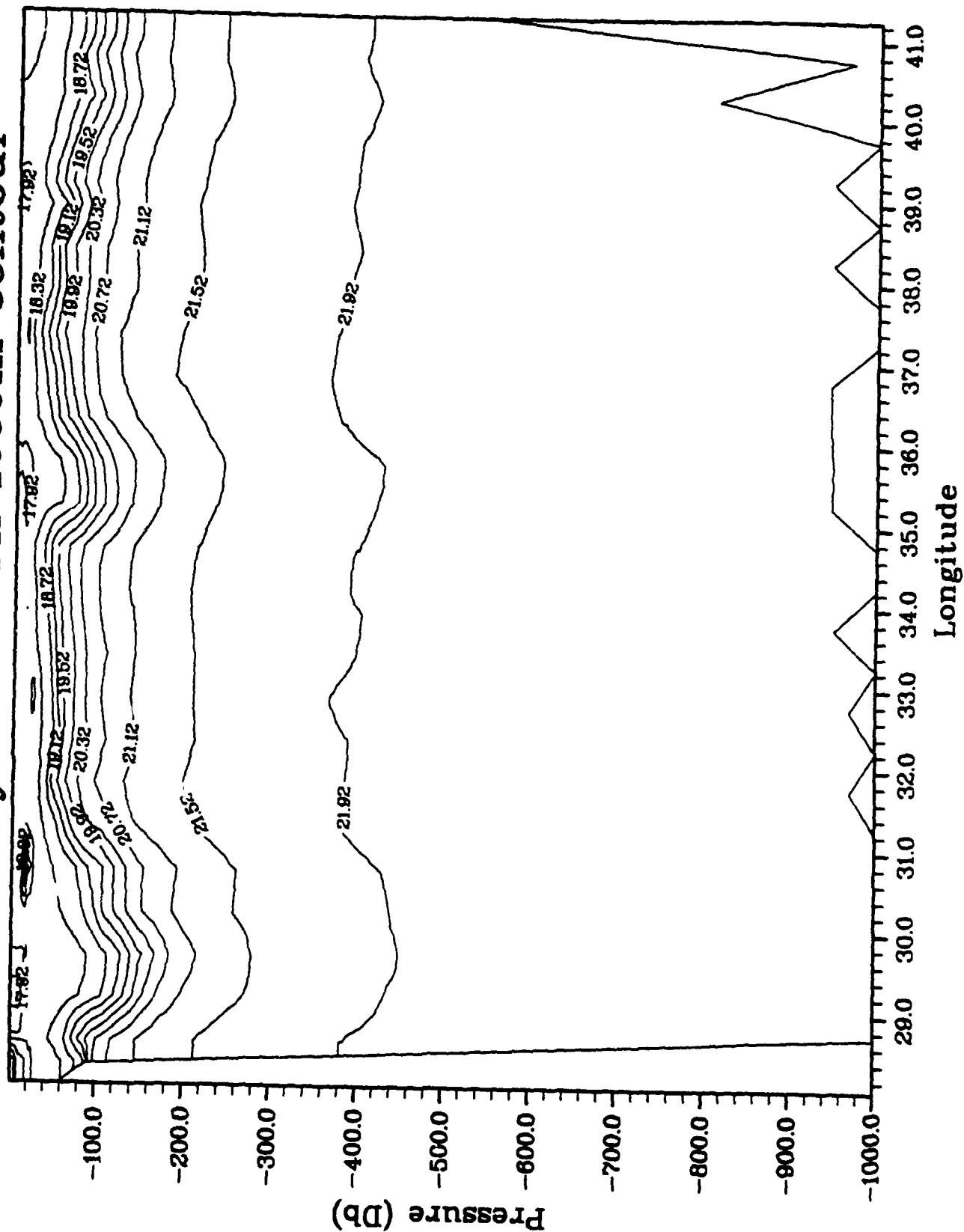


# Temperature: North 1000m Contour

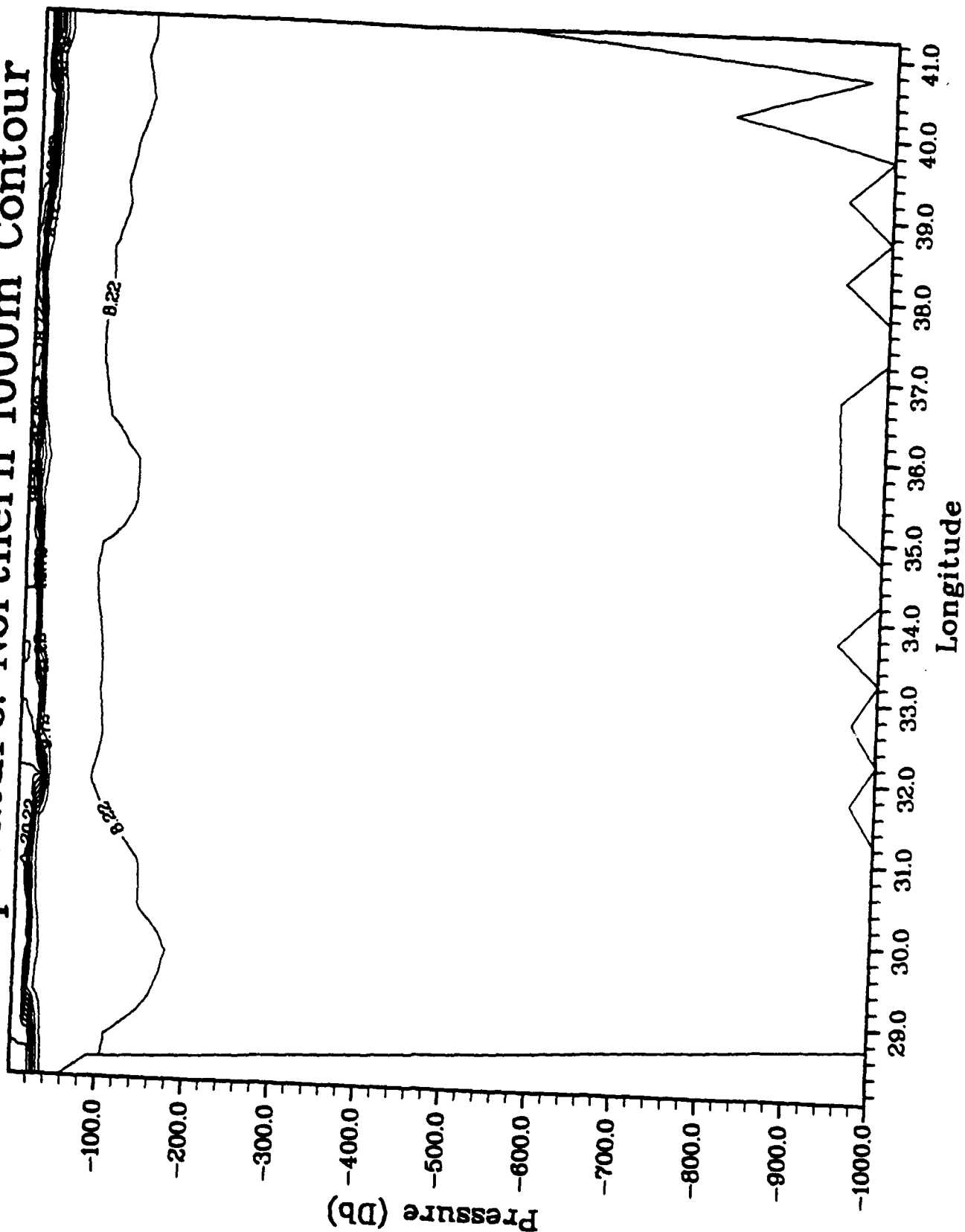




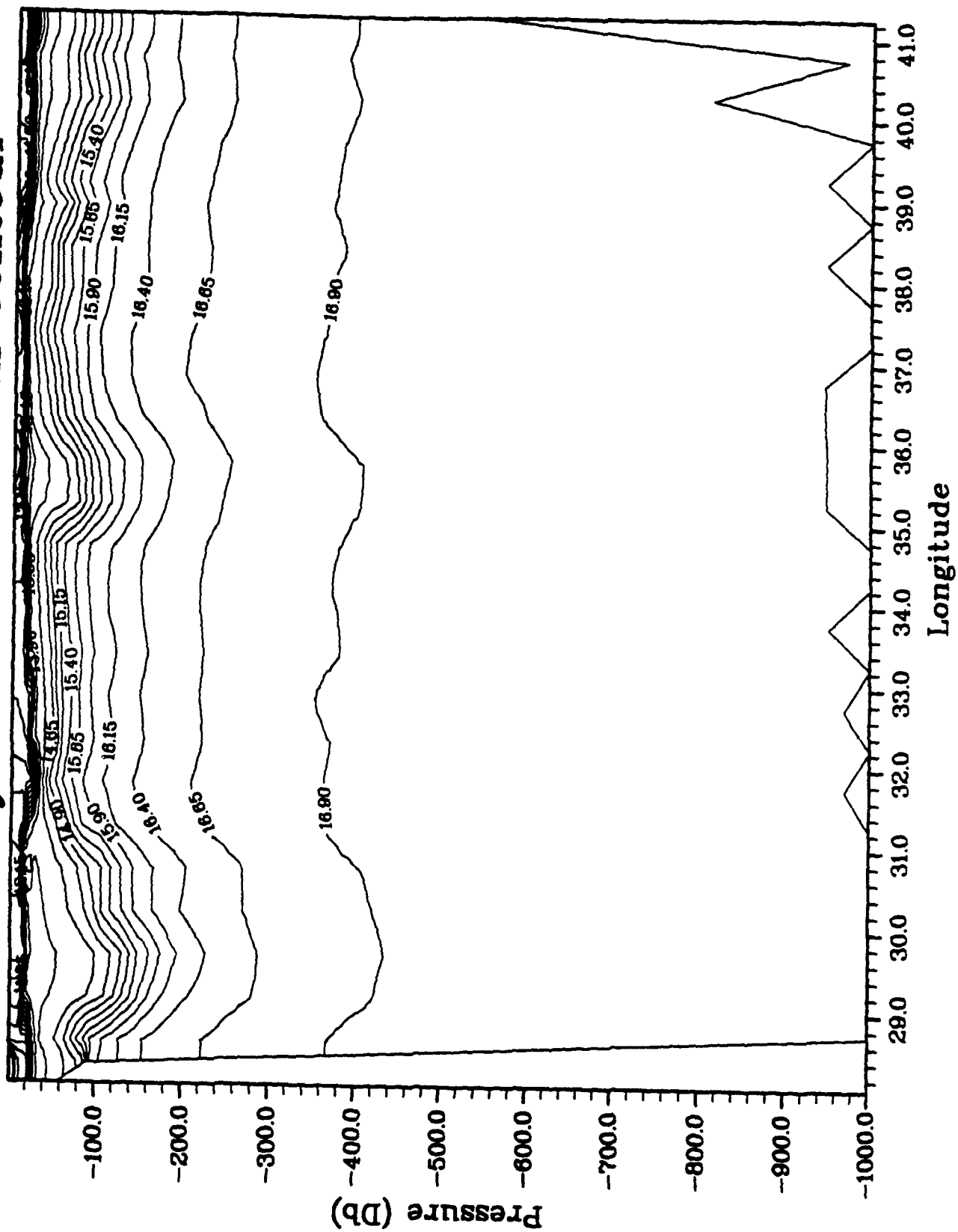
# Salinity: Northern 1000m contour



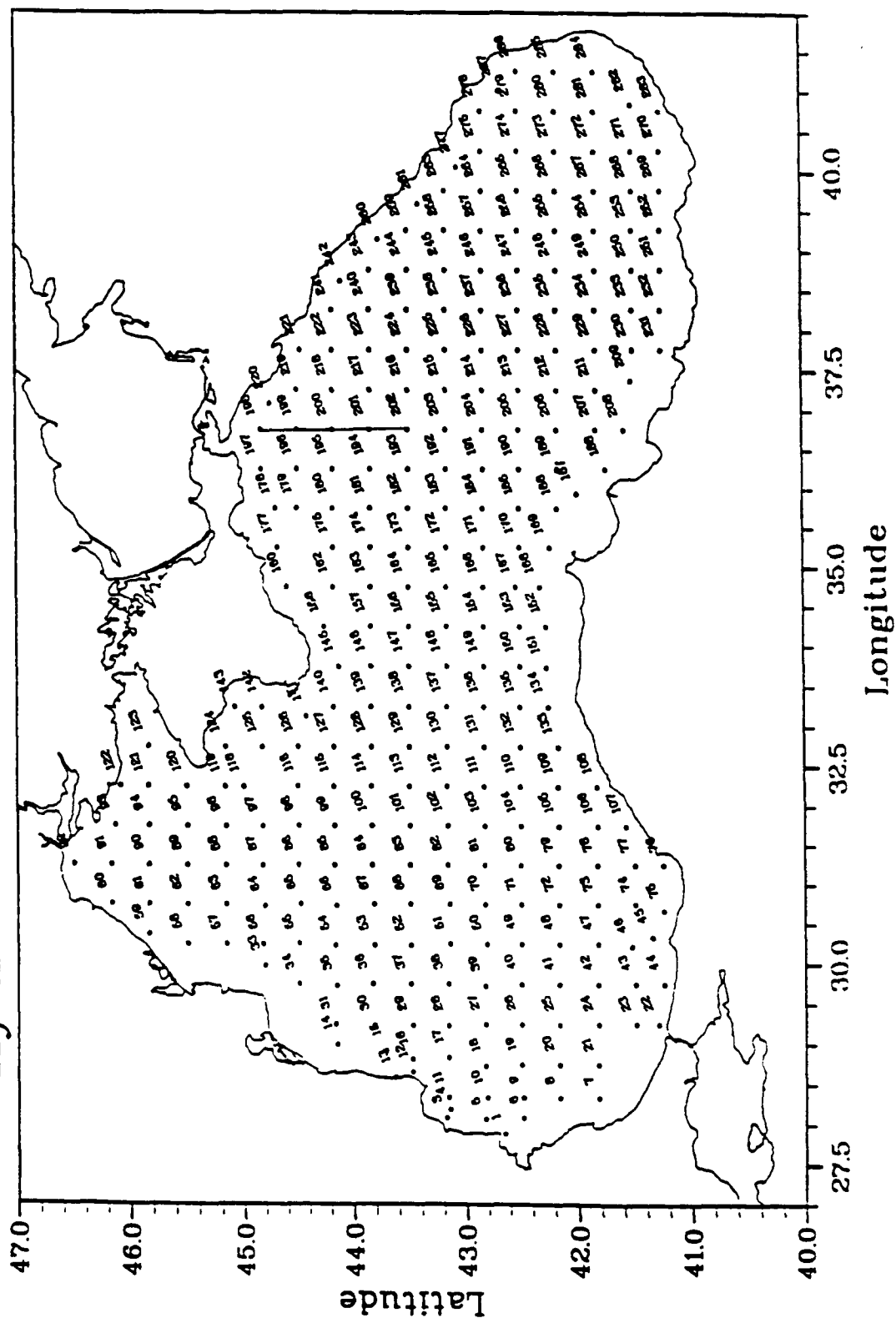
# Temperature: Northern 1000m Contour



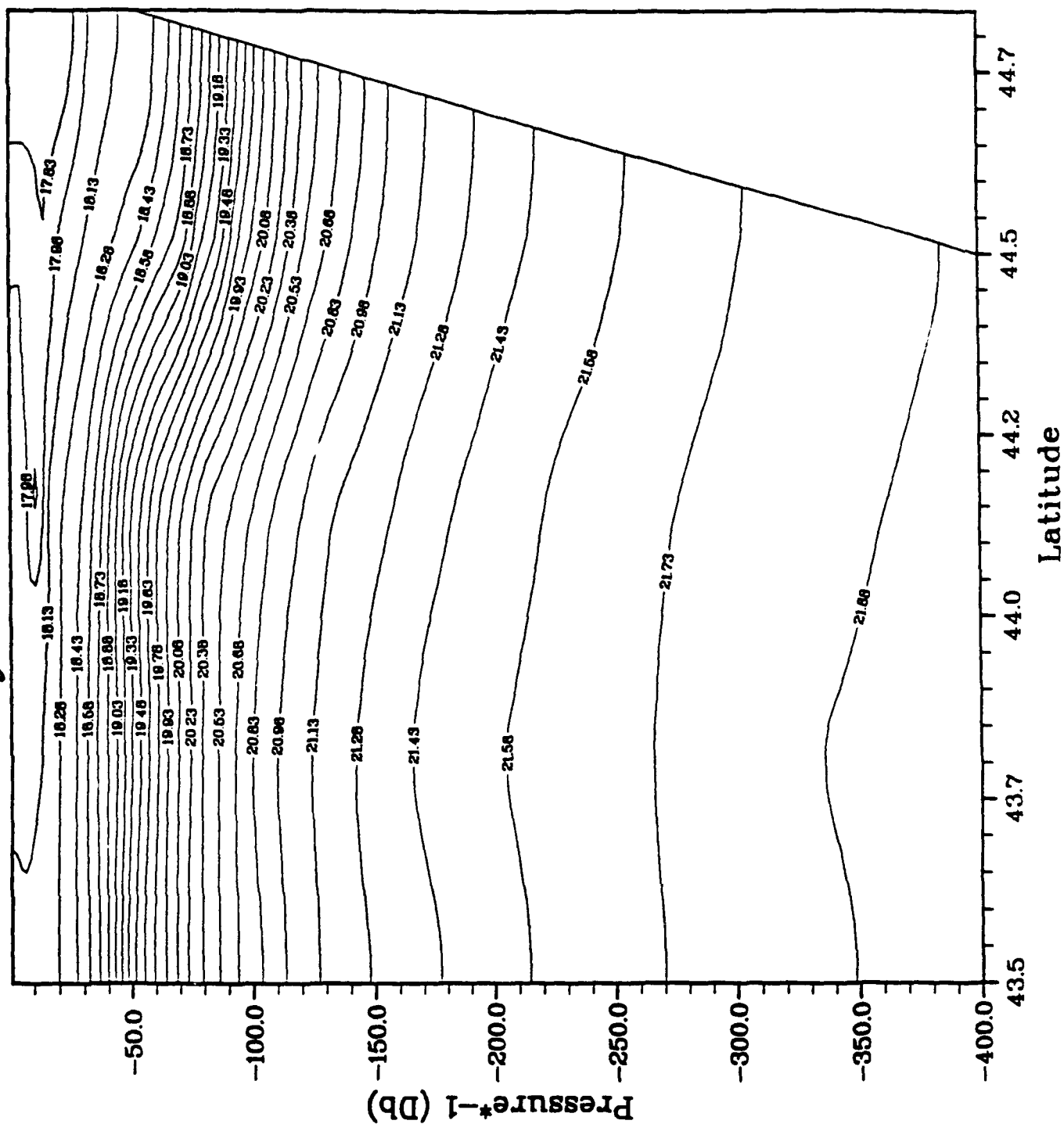
# Density: Northern 1000m Contour



# Hydro-Black 1991 Station Network

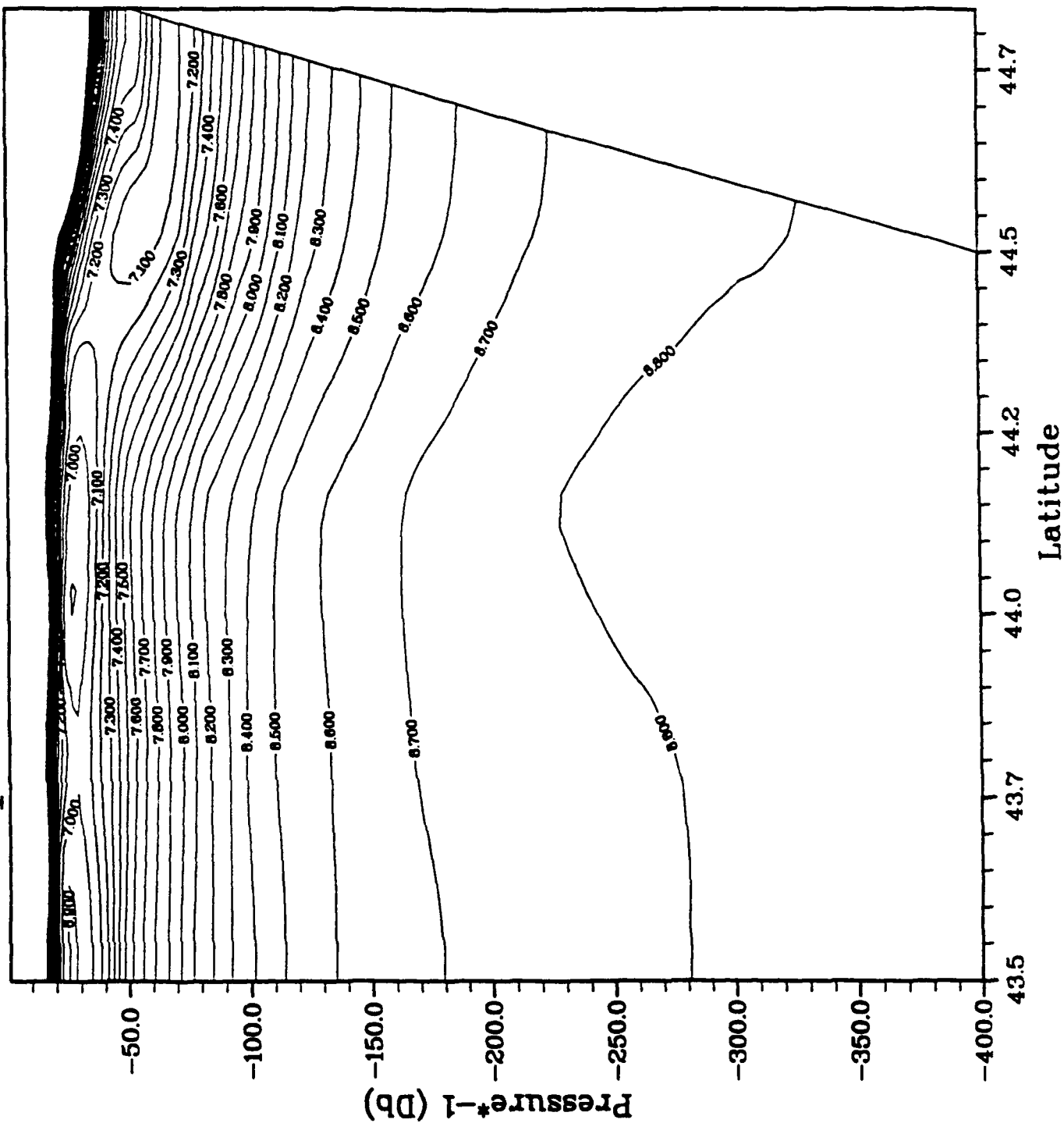


# Salinity: Stations 202 - 198

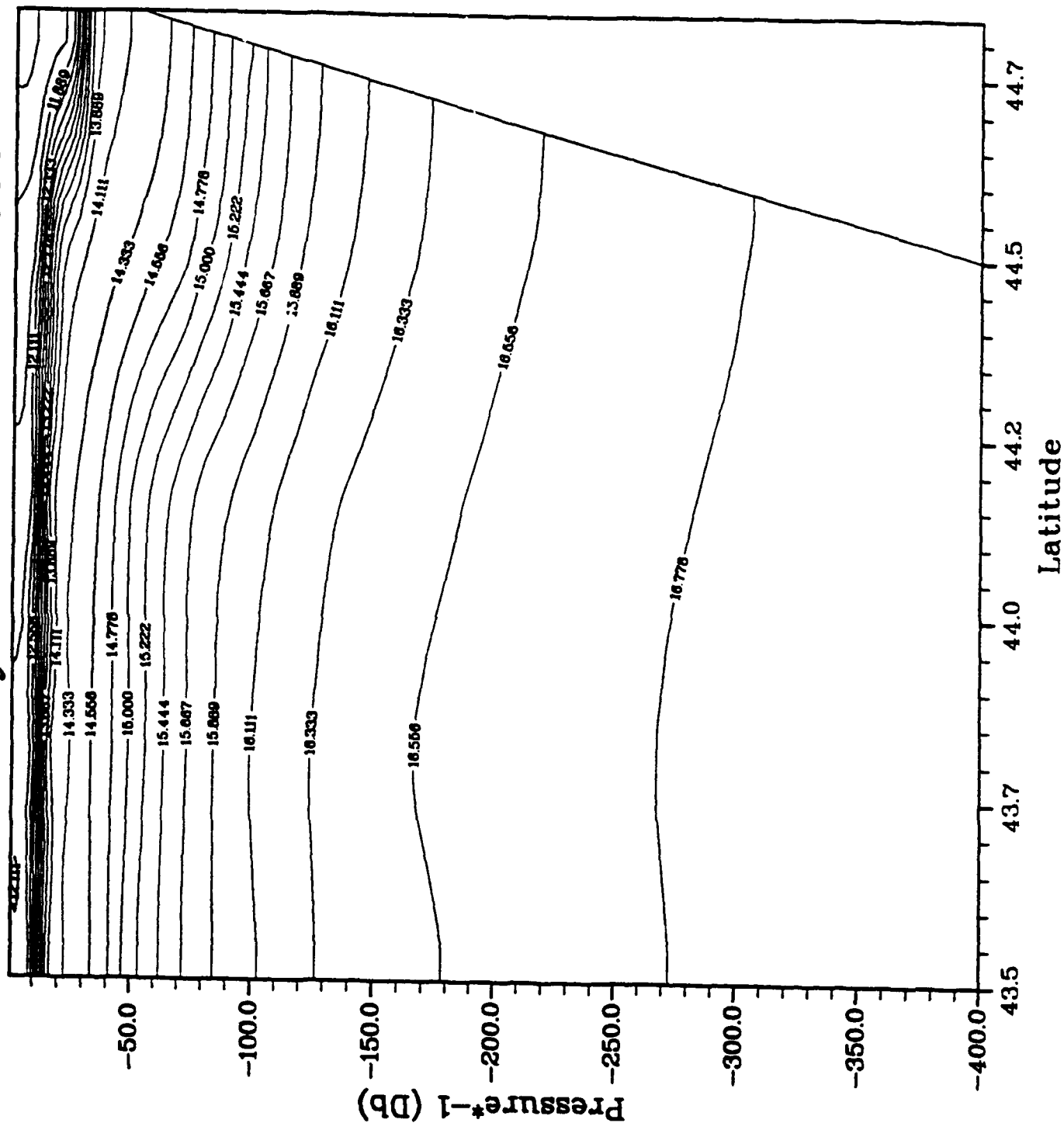




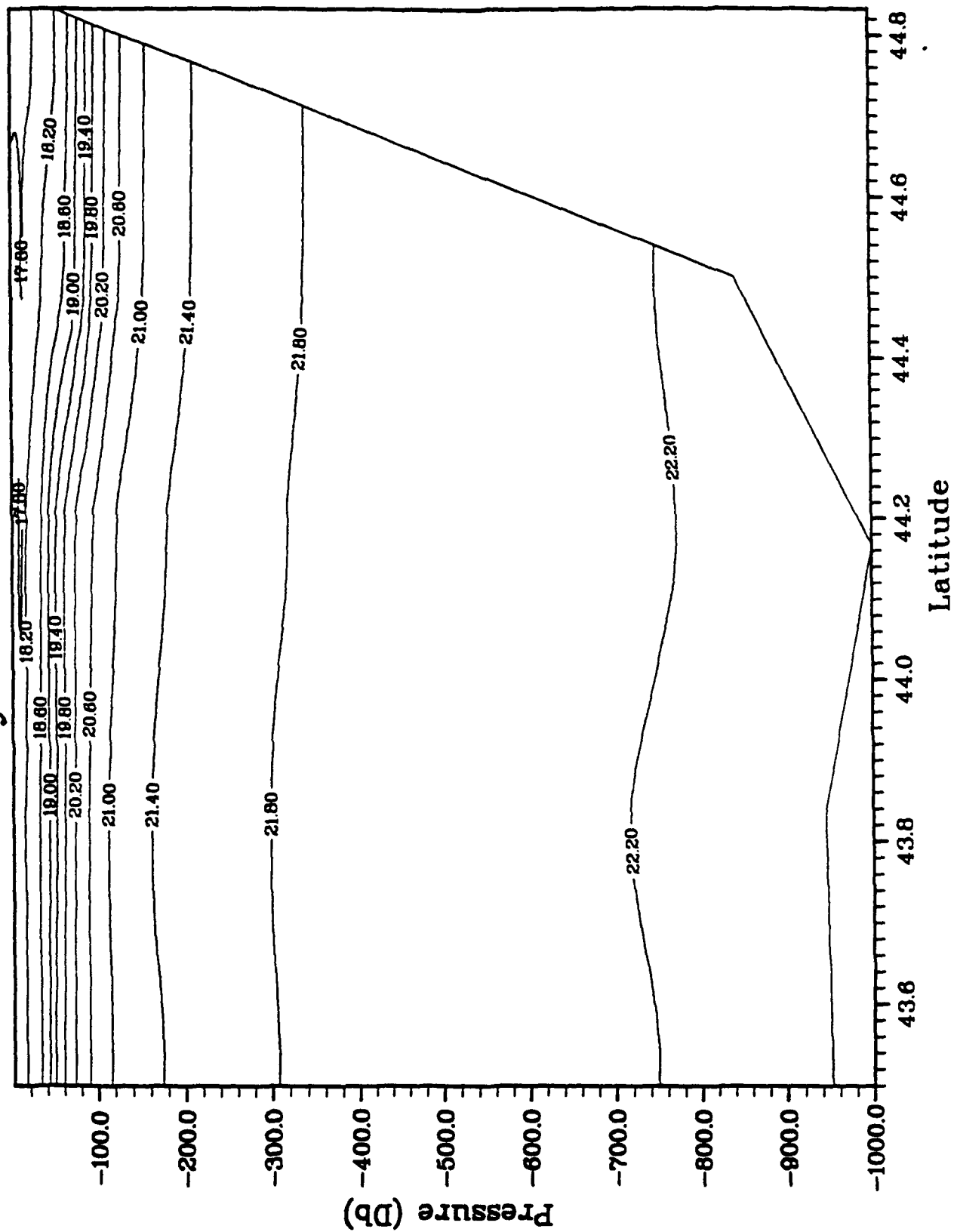
# Temperature: Stations 202 - 198



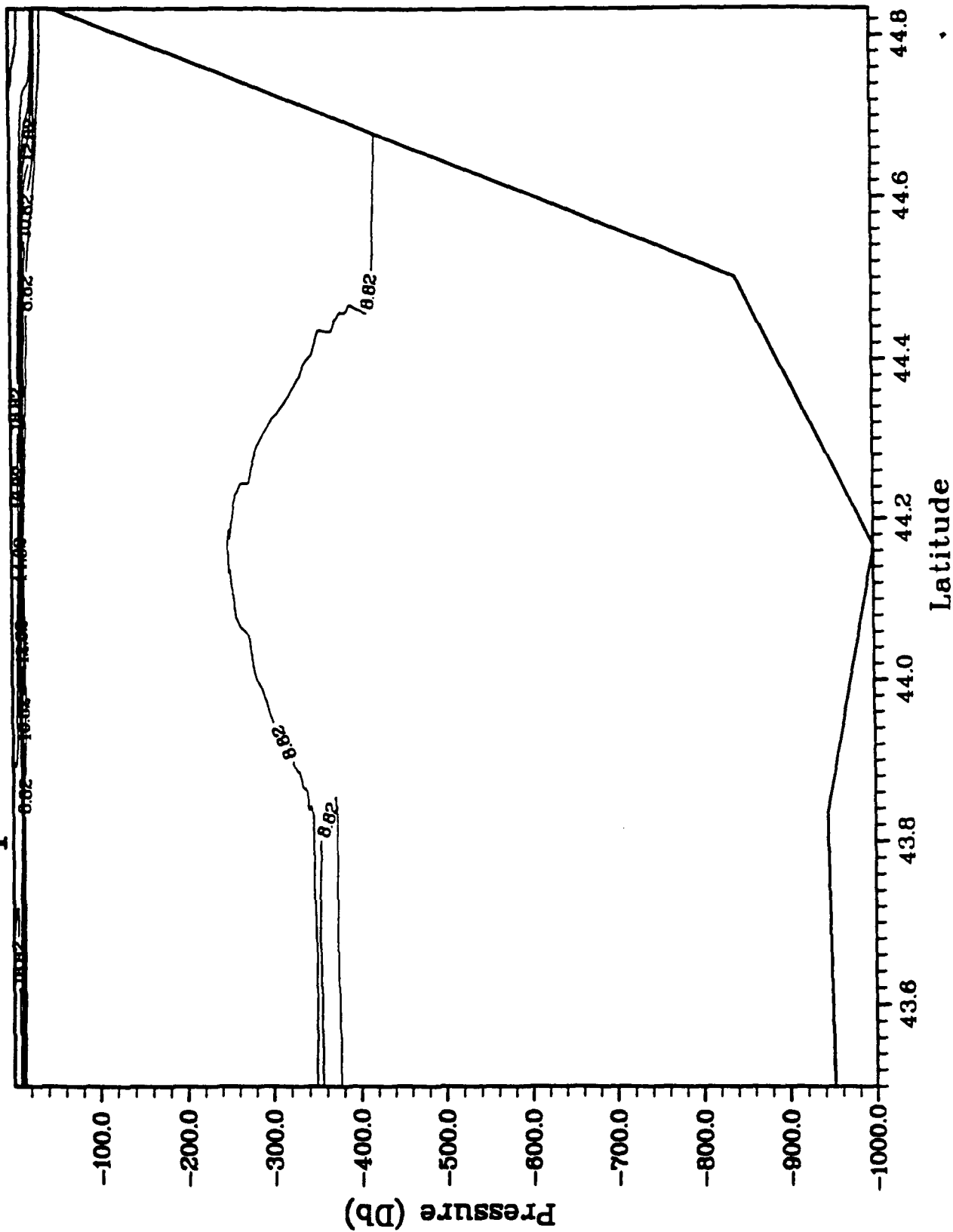
# Density: Stations 202 - 198



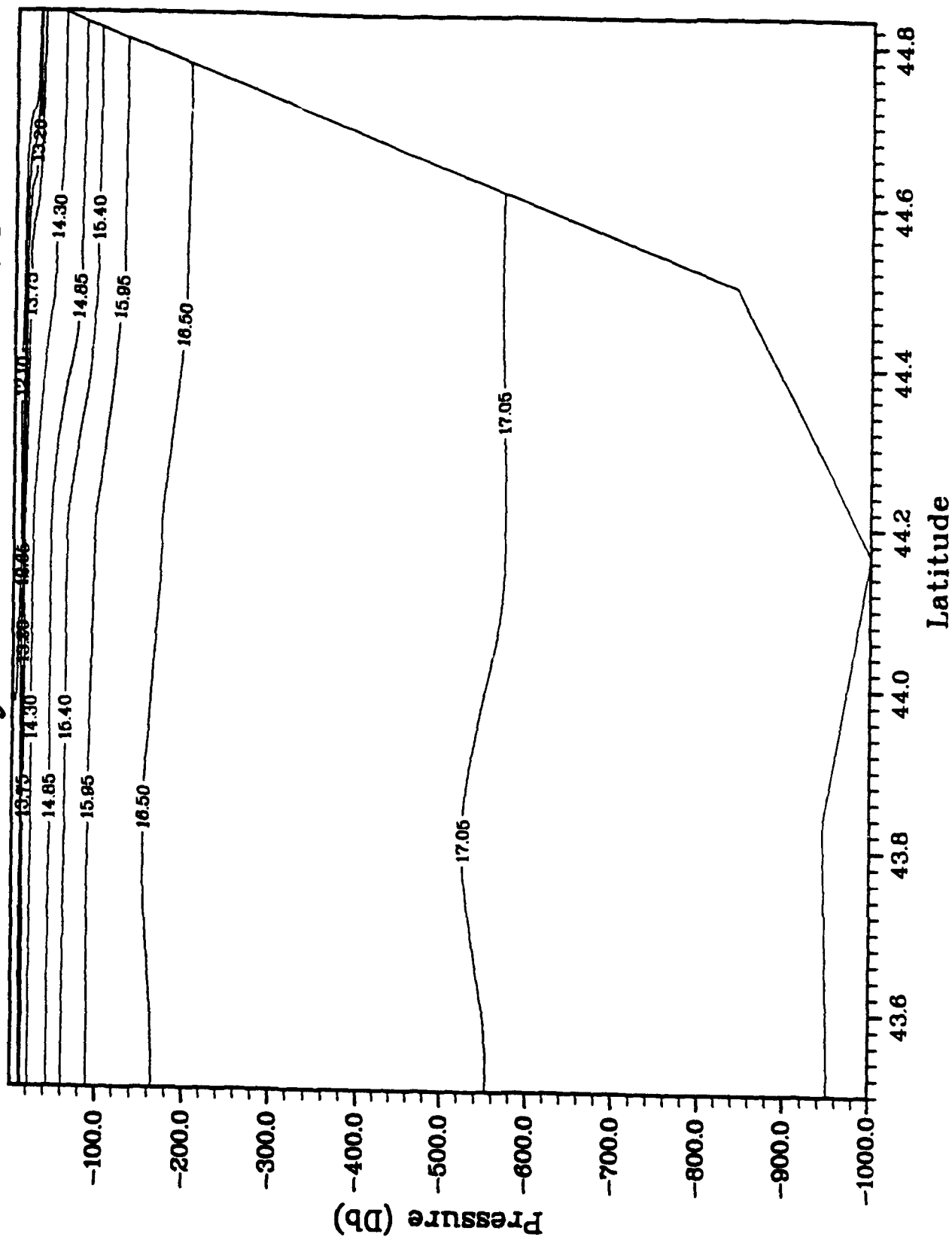
# Salinity: Stations 202 - 198



# Temperature: Stations 202 - 198



# Density: Stations 202 -198



**APPENDIX VI:**  
**LIST OF PARTICIPANTS**

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Oguz, Temel, Middle East Technical University, Erdemli, Turkey

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<b>16. Abstract (Limit: 200 words)</b>  An Intercalibration Workshop was held at the Woods Hole Oceanographic Institution (W.H.O.I.) from 1-10 December, 1991, for the CTD data acquired during HYDROBLACK '91. This intercalibration exercise was a prelude to an interdisciplinary HYDROBLACK '91 intercalibration to be held in Crimea, Ukraine, in February, 1992, incorporating the full suite of physical, biological, and chemical measurements acquired during the cruise.  HYDROBLACK '91 acquired for the first time a complete hydrographic, biological, and chemical data set for the entire Black Sea, to 2000 m water depth, with the participation of all Black Sea riparian countries as well as the U.S. Nearly 300 hydrographic stations were occupied to full water depth; biological and chemical measurements were made at 100 of these stations. This quasi-synoptic survey was accomplished using five ships during an interval of approximately three weeks.  Results show some disparities between CTD's from the different regions, but the intercalibrated results show a consistent and high resolution detail of the dynamic topography and other physical characteristics of the entire Black Sea basin. The intercalibrated data set is now available within each country and from W.H.O.I., and will form the basis for studies on ocean physics as well as interdisciplinary issues such as oxygen depletion within the basin and hydrogen sulfide distribution. This effort provides an intercalibrated, spatially-dense baseline against which all future and past measurements can be compared.  In spite of significant economic pressures arising from the changes in the eastern European countries, and the inadequate scientific exchange with the west during the past two decades, HYDROBLACK '91 is considered a success and a model for future international scientific and monitoring efforts throughout the Black Sea. Similar efforts are anticipated twice-yearly in the framework of the new Cooperative Marine Science Program for the Black Sea.			
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